Vol. IV. — No. 9. September, 1922.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION

[625 .13 (.44)]

The technical progress effected in the reconstruction of large bridges and viaducts on the French Northern and Eastern Railways.

Figs. 1 to 6, pp. 1196 and 1198

(*Le Génie civil.*)

On various occasions, the *Génie Civil*, with definite references on the subject, has reported on the systematic destruction caused by the Germans in the invaded regions of France, in the mines (1), in the factories (2), and in the means of communication (3).

On the subject of the last named, we have mentioned the two conferences held by Mr. Moutier at the French Society of Civil Engineers (4) in which he showed, not only the destruction carried out, but also the enormous amount of work that has been done towards the restoration of the whole of the Railway Systems and the reconstruction of the bridges and viaducts. We have also published, in abstract, an account of an important conference held at Lille, in which Mr. P. Javary, general superintendent of the French Northern Railway, reported on the very important reconstructional work carried out by this Railway Company (1).

Mr. Leinekugel Le Cocq, the well known bridge-builder, has thought it well to complete these notes, on the same subject, by a report on the method, the single purpose of the management and the technical progress made, — thanks to the French civil engineers — in the reconstruction of metal or concrete bridges and viaducts. On the 28 October, a noteworthy conference was held by him on this subject at the French Society of Civil Engineers of which we here reproduce the essential features. As the author states, the matter is not only one

(1) See *Génie civil*, 31 January 1920 (vol. LXXVI, No. 5, p. 113), of 17 and 24 July 1920 (vol. LXXVII, Nos. 3 and 4, pp. 45 and 69) and of 30 April 1921 (vol. LXXVIII, No. 18, p. 365).

(2) See *Génie civil* of 29 March 1919 (vol. LXXIV, No. 13, p. 245).

(3) See *Génie civil* of 5 April 1919 (vol. LXXIV, No. 14, p. 268).

(4) See *Génie civil* of 19 February 1921 (vol. LXXVIII, No. 8).

(1) See *Génie civil* of 9 July 1921 (vol. LXXIX, No. 2, p. 25).

of recording what has been done but actually interest at the present time because it involves some important conclusions.

It will be possible, in particular, to draw invaluable data from this with regard to the progress that is being made in the reconstruction of bridges and viaducts and to show two new methods to which we should give consideration when undertaking the construction of large bridges and viaducts in the future. One of these methods consists in the application of concrete to spans that have not been considered suitable up to the present time; the other is in the use of high tensile steels under special conditions.

The method employed and the unification of management adopted in the reconstruction of bridges and viaducts in the invaded regions. — Mr. Leinekugel Le Cocq investigates in succession the method used and the management adopted by both the French Northern and the French Eastern Railway Companies and by the Ministry of Public Works for the reconstruction of bridges and viaducts in the invaded regions.

From the day after the victory of the Marne those French engineers, who, by age or duties, were kept from the front, clearly saw the enormous effort that would be asked of them, once the enemy had been driven over the frontiers. This foresight was one of the essential factors in the rapid restoration of all the bridges and viaducts either in a final or in a temporary form.

Bridges and viaducts of the French Northern Railway Company. — The civil engineers in charge of the constructional work of this Company, notwithstanding the heavy task that confronted this work during the war, in having to maintain the traffic by makeshift and temporary methods in the non-invaded regions, devoted their efforts, from the day after the victory of the Marne, with absolute method and singleness of purpose, to drawing up a simple, precise and economical programme which Mr. Leinekugel Le Cocq gives in considerable detail.

This programme comprised the revision of the schemes for reconstruction of all bridges and viaducts on the Railway System. All spans carrying the railway were divided into three main classes :

A. — The first class was carried out by means of spans known as « omnibus » of which there were four main types :

Type I, of which there were seven models *a*, *b*, *c*, *d*, *e*, *f*, *g*, of progressively increasing spans up to about 7 m. (22 ft. 11 5/8 in.) was adopted in 308 instances, of which :

282 spans were for single-track for the French Northern Railway measuring	1 251 m. 90 (4 107 ft. 4 in.).
26 spans were for single-track for mines and light-railways measuring	112 m. 40 (368 ft. 10 in.).
Total. . .	1 364 m. 30 (4 476 ft. 2 in.).

Type II of which there were two models, *a* and *b*, also of progressively increasing spans up to about 10 m. (32 ft. 10 in.), was adopted in 41 instances, of which :

28 spans were for single-track for the French Northern Railway measuring	245 m. 40 (805 ft. 2 in.).
13 spans were for single-track for mines and light-railways measuring	123 m 65 (405 ft. 8 in.).
Total. . .	369 m. 05 (1 210 ft. 10 in.).

Type III of which there were five models, a_1, a_2, b_1, b_2, b_3, for spans up to 15 m. (49 ft. 3 in.) was adopted in 42 instances, of which :

31 spans were for single-track for the French Northern Railway measuring	380 m. 65 (1 248 ft. 10 in.).
11 spans were for single-track for mines and light-railways measuring	153 m. 30 (503 feet).
Total. . .	533 m. 95 (1 751 ft. 10 in.).

Finally, type IV, of which there were three models, A, B, C, for spans from 13 m. 20 up to 28 m. (43 ft. 4 in. to 91 ft. 10 in.), was adopted in 82 instances of which :

62 spans were for single-track for the French Northern Railway measuring	1 240 m. 50 (4 070 feet).
20 spans were for single-track for mines and light-railways measuring	389 m. 50 (1 277 ft. 10 in.).
Total. . .	1 630 m. 00 (5 347 ft. 10 in.).

To sum up, the first class of these spans known as « omnibus » for single tracks, with its four main types, comprised 454 spans of a total length of 3 896 m. 9. (12 785 ft. 4 in.)

It is possible from these figures, to appreciate the great services rendered by these schemes, that had been worked out in advance.

The schemes enabled: a great economy in time and cost of design to be effected as well as a simplification and a reduction of the work for the rolling mills, for the constructional works, and for the assembling and riveting on the spot.

The forming of riveting gangs, for the work at the erecting yards, had occupied much attention in the preparation of these schemes for carrying out the work. The adaptability, the skill and the intelligence of the staff of workmen employed met all calls, because, contrary to the fears that had been felt, there was never a shortage of riveters at any moment during the work of erection.

The spans of this first class were web-girders and present no particular technical feature.

Figure 1 shows an « omnibus » bridge of type IV, B; this is the Marchiennes bridge over the Scarpe on the Somain-Orchies line at km. 236.889 (at mile 147.199). It is of 20 m. 50 (67 ft. 3 in.) span, the main girders are 2 m. (6 ft. 6 3/4 in.) in height, the vertical stiffeners are spaced 1 m. 50 (4 ft. 11 in.) apart, and the stays are placed 3 m. (9 ft. 10 in.) apart, except at the ends.

B. — The second class of bridges, the schemes for which were prepared in advance, also in accordance with the test load of the regulation dated 8 January 1915 (1), includes all metal spans of which the opening is greater than 28 m. (91 ft. 10 in.).

In this class of works the type of bridge with large girder openings was adopted almost universally. The old method, which took as the rule, that the height of the main girders sould be one tenth of the span, was abandoned. By this alone a considerable economy was effected in metal and at the same time an appreciable reduction in the time of erecting and of riveting on the spot.

To bring to light the saving effected

(1) A detailed analysis of this regulation which replaces the Ministerial Circular letter of 29 August 1891, was given in the *Génie civil* of 23 October 1915 (vol. LXVII, No. 17, p. 258).

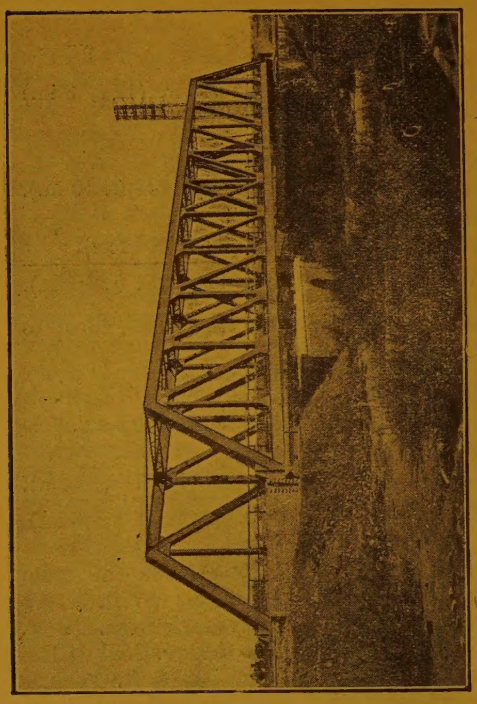


Fig. 2. — Courrières bridge, over the Haute-Deule.

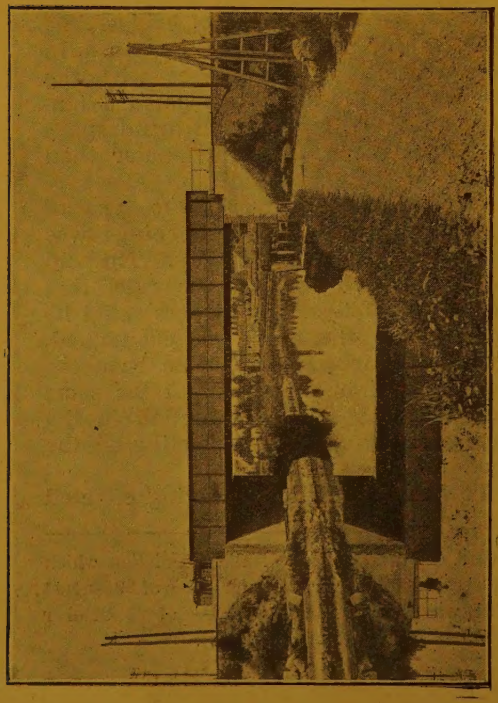


Fig. 1. — Bridge of « omnibus » type, at Marchiennes, over the Scarpe.

in metal it is only necessary to refer to the following equation :

$$p = 0.60 \sqrt{L}$$

which gives the weight in tonnes per metre run of span, for a single track, for an opening of length L, expressed in metres. This simple law applies to all the schemes drawn up and carried out by the French Northern Railway Company, for values of L, not exceeding 70 m. (229 ft. 8 in.) and for the double-headed test train of the last regulation dated January 1915. It should be noted, however, that the weight p does not include the bearing shoes.

The metal railway-carrying spans, previously constructed, in accordance with the regulation of the Ministerial Circular letter of 1891, conformed with the equation ;

$$p = 0.42 \sqrt{L}$$

for spans of 30 to 50 m. (98 ft. 5 in. to 164 feet), exclusive of the metal flooring.

If account is taken of the difference between the weight of the test trains under the old and the new regulations, the old classes of bridges and viaducts that have been reconstructed would have required a quantity of metal given by the equation :

$$p = 0.71 \sqrt{L}$$

The difference is very appreciable. Thus for a single-track bridge of 50 m. (164 feet) opening, for example, the old method would involve the use of an extra amount of metal of 38 t. 90 (38.3 English tons.).

Now this second class of special works, is represented on the French Northern Railway system by :

116 spans for single-track having a length of 3 467 m. (11 374 ft. 10 in.).

and for mines and light-railways, by :

25 spans for single-track, having a total length of 1 327 m. 65 (4 355 ft. 10 in.).

In all 141 spans having a total length of 4 794 m. 65 (15 730 ft. 9 in.). From the preceding example the important economy effected in the gross weight of all these girder-bridges will be appreciated.

Mr. Leinekugel Le Cocq gives the following examples of spans of this second class of girders having large openings.

Figure 2 shows the Courrières bridge over the Haute-Deule at km. 225.560 (at mile 140.159), on the Hénin-Liétard line at Don. This is a skew bridge; its opening, measured at right angles to the abutments, is 36 m. 35 (119 ft. 2 in.); the length of the span is 48 m. 52 (159 ft. 2 in.). The height of the main girders is 6 m. 50 (21 ft. 4 in.); the distance between-upright members is 4 m. 65 (15 ft. 3 in.) except at the ends.

Figure 3 shows the normal bridge over the Lys at Commines for the Lille-Commines line at km. 21.400 (at mile 13.298). Its opening is 37 m. 80 (124 ft. 3/8 in.), the height of the main girders is 6 m. 50 (21 ft. 4 in.); the distance between uprights is 4 m. 66 (15 ft. 3 1/2 in.) except at the ends.

To sum up, the two first classes comprise in all 595 metal railway-bridge spans representing a total length of 8 691 m. 55 (28 516 ft. 1 in.).

C. — The third class, which completes the bridges and viaducts carrying the railways, comprises all normal or skew concrete bridges, seven of which are in reinforced concrete. It comprises 244 pieces of work, exclusive of culverts of 2 m. (6 ft. 6 3/4 in.) span, amounting to a total length of 5 409 m. (17 746 ft. 5 in.).

These bridges are arched; in one of them, situated in Belgium, on the line from Erquelinnes to Charleroi, the arch is as much as 63 m. (206 ft. 8 3/8 in.) span between the springings and its rise is about one tenth (fig. 6). The design for this reinforced-concrete bridge is due to Mr. Candelier, Chief Designing Engineer to the French Northern Railway Company, who entrusted the final detail designing to Mr. Freyssinet, the engineer who is well known for other very interesting works, particularly the bridge of Villeneuve-sur-Lot which he himself described in the *Génie Civil* of 30 July, 6 and 13 August 1921 (1).

Apart from these railway bridges the constructional department of the French Northern Railway Company had also to prepare schemes in advance for the execution of all road-bridges crossing over the railways.

The same rational method of grouping these works led to their classification in three well-defined groups :

Bridges of ordinary or reinforced concrete with arches;

Bridges of reinforced concrete on piers;

Metal bridges with encased roadway girders or of reinforced cement.

The classification in each series was greatly simplified by the fact that the Ministry of Public Works, through the central service of technical designs, formed after the war, also secured, as will be seen below, a single department for dealing with the matter which gave the greatest service. This service, at the time of the reconstruction of the road-bridges, determined very definitely that the widths adopted for the roads, with rare exceptions, should be, 3 m., 5 m. 50 and 6 m. (9 ft. 10 in, 18 ft. 1/2 in. and 19 ft. 8 in.) for the bridges which carry respectively occupation roads (routes vicinales), carriage roads (routes départementales) or main roads (routes nationales).

By this means all variations in the widths of roads and footpaths, which

(1) At the same time as the description of this work appeared, Mr. Freyssinet published in our columns of a very interesting theory relating to long-span bridges in ordinary concrete. (See *Génie civil*, vol. LXXIX, Nos. 5 to 7).

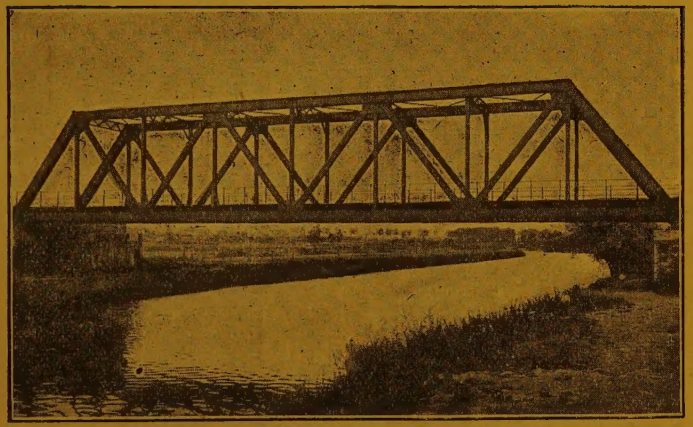


Fig. 3. — Commines bridge, over the Lys.

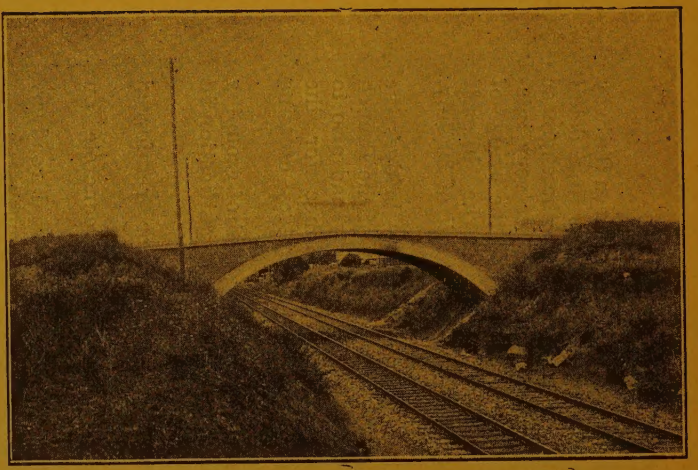


Fig. 4. — The Sebastopol bridge, on the Amiens line at Tergnier.

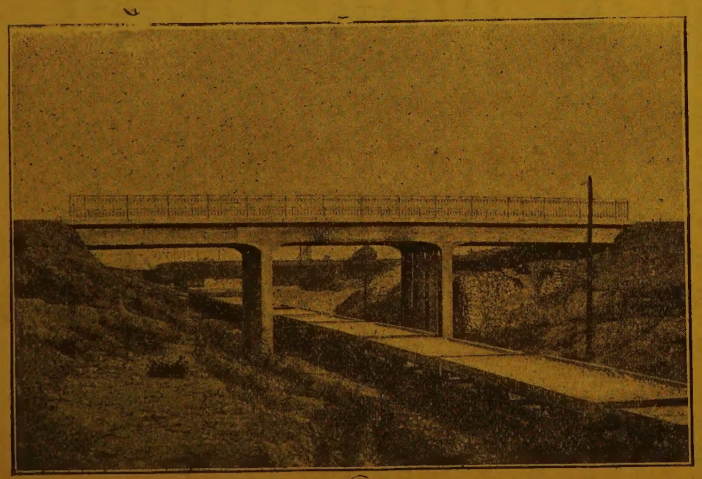


Fig. 5. — Reinforced-concrete bridge, over the Méricourt junction.

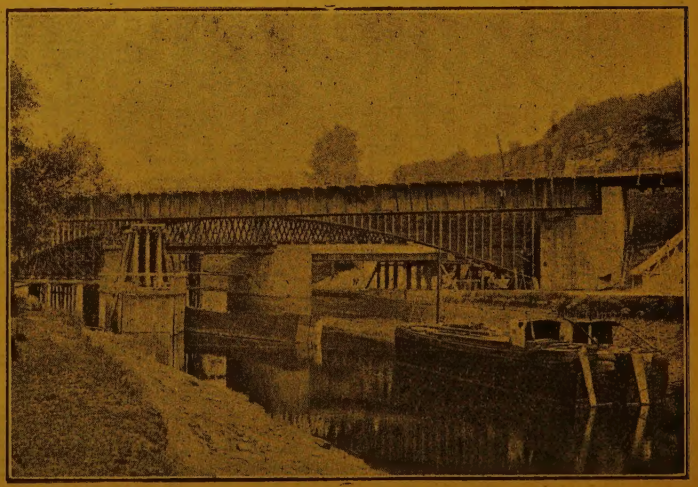


Fig. 6. — Reinforced-concrete arch of 63 m. (206 ft. 8 3/8 in.) span.

before the war were without limits, have been eliminated in a rational manner.

The number of road bridges of the first class with concrete arches is 24, representing a total length of 677 m. 30 (2 222 feet).

Figure 4 shows, on the Amiens-Tergnier line, at km. 61.144 (at mile 37.994), the over-bridge, known as the Sebastopol bridge, on main road No. 198. The centerings which were used for the execution of these arches were made in advance, sometimes of wood and sometimes of metal. They were of « omnibus » type and, through the detail parts used, increasing widths of the span were obtained.

The number of road-bridges of the second class in reinforced concrete on piers is 101, representing a total length of 2 986 m. 30 (9 797 ft. 9 in.).

Figure 5 shows a reinforced-concrete bridge on the Méricourt junction line at km. 1.934 (at mile 1.202). This bridge carries departmental road No. 33 and requires four sets of piers to carry it in consequence of its length.

The third series of metal road-bridges with roadway of metal encased in cement or in reinforced concrete, and with brickwork abutments, comprises 16 bridges having a total length of 418 m. 95 (1 374 ft. 6 in.).

In recapitulating the above figures, we find that for the French Northern Railway Company alone :

1° The number of rail-bridges reconstructed amounts to 839 having a total length of 14 100 m. 55 (46 262 ft. 6 in.);

2° The number of road-bridges over the railways is 141, having a total length of 4 082 m. 55 (13 394 ft. 5 in.).

In all, for rail bridges and road bridges 980 bridges having a total length of 18 183 m. 10 (59 656 ft. 11 in.).

It should be noted that small viaducts up to 3 m. (9 ft. 10 in.) span are not included in this statement.

Bridges and viaducts of the French Eastern Railway Company. — On this railway, the same spirit in method and management prevailed as on the French Northern Railway.

The total of the bridges and viaducts destroyed was also methodically classified, in three distinct and special classes for railway bridges.

The first class for all bridges and viaducts of a span not exceeding 14 m. (46 feet) was carried out with metal spans with encased girders.

The second class for all spans, in which the available height allowed it, comprised arched bridges of concrete; the centerings used were in the first instance of rails and later of rolled sections bent hot (1). These centerings serve by themselves, with the help of stirrups, to carry the shuttering for the soffits and string-courses of the arches.

The third class comprises the metal long-span bridges over the Meuse, the Aisne and the Oise at Rethel, at Rilly and Senuc, and over the canal at Rheims.

The total number of bridges and viaducts entirely demolished was 202 brickwork bridges, of which 17 were large bridges of 70 to 120 m. in length (230 to 394 feet) over the Meuse, the Orne, the Aisne, the Aire and the Marne; and also 162 metal bridges.

The figures for the bridges that have been completely reconstructed up to the date of 15 August 1921 are as follows :

1° For railway bridges :

Brickwork bridges :

117	of 1 to 10 m. (3 ft. 3 in. to 32 ft. 10 in.) span.
18	of 10 to 30 m. (32 ft. 10 in. to 98 ft. 5 in.) span.
10	of 30 m. (98 ft. 5 in.) span and over.
Total. . .	145

(1) See on the subject of this method of construction, *Génie civil*, 7 April 1917 (vol. LXX, No. 14, p. 227) and 11 January 1919 (vol. LXXIV, No. 2, p. 24).

Metal bridges :

126 of 1 to 10 m. (3 ft. 3 in. to 32 ft. 10 in.) span.
14 of 10 to 30 m. (32 ft. 10 in. to 98 ft. 5 in.) span.
11 of 30 m. (98 ft. 5 in.) span and over.

Total. . . 151

2° For road-bridges over railways, out of 56 in course of construction, 21 had been completed by 15 August 1921.

Bridges and viaducts reconstructed by the Ministry of Public Works. — There remain a few words to be said on the method adopted by the Ministry of Public Works for solving the serious and difficult problem of the reconstruction of bridges and viaducts in the invaded regions.

In order to obtain : on the one hand, unity in management and method; on the other hand, great economy in time and cost of the reconstruction of all these works, the Ministry of Public Works created a Central Service for technical work under Mr. Pigeaud, inspector general of roads and bridges, who was entrusted, moreover, during the war, with the work for reconstructing the necessary bridges in the rear of the fighting armies. The method adopted by this Service was to repair, by temporary methods, in a few months after the Armistice, all breaches which rendered the roads in the invaded regions unusable.

This first stage having been covered with complete success, the Central Service gave instructions to all sections of the department of roads and bridges in the various devasted departments to deal with on the spot, or subject to instant decision, the reconstruction of bridges of which the opening did not exceed 40 m. (131 ft. 3 in.) by types that had been carefully designed and reduced to a small number.

For the other bridges of large span, the Central Service of technical design brought together the characteristic features of each of the bridges or viaducts that were to be reconstructed. It then sent out three successive invitations to all bridge-constructors for tenders, which is the logical and rational method that gives the best results, both from the economic point of view for the Treasury and from the point of view of progress.

Moreover, in the case of the constructors themselves, this unity of technical management has the greatest advantages; the modifications to the constructors' schemes, which are suggested to them and asked of them, are the results of observations and studies and effect considerable improvement.

Mr. Leinekugel Le Cocq mentions the two main reasons why the reconstruction of these road-bridges has not been pushed forward more actively.

In the first place, the provisional bridges have re-established communication over the whole of the road system, it was therefore right to push forward with maximum effort the bridges and viaducts of the vital arteries of communication of the country, that is to say, on the railways. Later, the financial effort that France was exerting alone, without assistance from her Allies, had necessarily to be spread over several years.

Among all these road-bridges, of more than 3 m. (9 ft. 10 in.) span, of which the number amounts to 2 005, to be reconstructed in the invaded regions, there are actually 491 rebuilt or in course of reconstruction, having a total length of 9 558 m. (31 358 ft. 10 in.) which represents about one fourth of the total work to be carried out.

This is a very great effort that has been made both by the Central Service of technical design and by the French contractors.

CONCLUSIONS TO BE DRAWN FROM THE PARTICULARS DERIVED FROM THE RESULTS OBTAINED. — Mr. Leinekugel Le Cocq

considers that two important results have been obtained from the work done in practice.

The first result relates to the use of concrete for the construction of long-span bridges in the future, even for normal railways carrying heavy traffic.

The reinforced-concrete bridge of 63 m. (206 ft. 8 1/2 in.) opening at the springings (fig. 6), that has just been completed on the Erquelinnes-Charleroi line, which we have mentioned above, represents double the span that it had been dared to use hitherto for reinforced concrete for a main line of railway carrying heavy traffic. This indicates a new view regarding the construction, in some cases, of bridges of great span for roads and railways.

The Risorgimento bridge (1) of 100 m. (328 feet) opening in reinforced concrete, constructed in 1910 in Rome, had commenced the era of large-span arches for road-bridges. To go from this to the application to railways, it was necessary to consider the remarkable results obtained by Mr. Freyssinet in his bridges and viaducts carried out with concrete arches, particularly the road-bridge of the Veurdre over the Allier in 1911, with a central arch of 72 m. 50 (237 ft. 10 1/2 in.) span, and of 5 m. 20 (17 ft. 3/4 in.) sagitta; the road-bridge of Villeneuve-sur-Lot in 1920, with a central arch of 98 m. (321 ft. 6 1/2 in.) span and of 13 m. 054 (42 ft. 10 in.) sagitta; and in those which are in course of construction, particularly : the road-bridge of St. Pierre-du-Vauvray, on the Seine with a central arch of 131 m. (429 ft. 9 1/2 in.) and 25 m. (82 feet) sagitta; and the viaduct crossing the valley of the Bernand stream on the Balbigny-Regny line (Loire) with a central arch of 170 m. (557 ft. 9 in.) span and a sagitta of 29 m. 65 (97 ft. 3 1/2 in.), a bridge commenced in 1914 but interrupted by the war (1).

This new view is likely to be still further extended if the means are considered, as has already been proposed in the scheme which the *Génie civil* will shortly describe, for getting free entirely from the great quantity of timber at present used to carry the centerings. All this wooden framing is not only costly, but has the great disadvantage of getting out of shape under the influence of loads and of variations of climate : rain or drought.

The solution of the future, also based on the particulars of the application of the « omnibus » centerings used by the French Northern Railway Company, consists in carrying over the gap, at any height whatsoever, removable shuttering arranged for arches of great variation in span by means of isostatic rope-systems, adjustable to meet the elastic variations under gradually increasing loads as well as the variations of temperature.

It is superfluous to show here that these rope systems solve the problem of removing the centerings in the most simple manner.

It will be seen that the new aerial arrangement for removable shuttering, which will doubtless receive its first application in France, points to real progress; it will, moreover, only be an improvement on the method used by Mr. Mercier, at the time of the construction, ten years ago, of a large masonry arch, 90 m. (295 ft. 3 1/2 in.) opening, over the Rhummel at Constantine, in Algeria (2). The large centerings of timber of large size were carried in this bridge, at different points, by an adjustable rope system devised and worked

(1) See the description in the *Génie civil* of 23 March 1912 (vol. LX, No. 21, p. 408).

(1) For the description of all these bridges and viaducts, see *Génie civil* of 15 January 1921 (vol. LXXVIII, No. 3, p. 49).

(2) See the description of this bridge in *Génie civil* of 1 March 1913 (vol. LXII, No. 18, p. 341) and a more detailed description in the *Annales des ponts et chaussées* (III-1912).

out by Mr. Leinekugel Le Cocq, jointly with Mr. F. Arnodin.

The fullest advantage of these new methods can only be obtained, with the complete safety and economy that are desirable, if use is made of selected materials in the execution of these bridges; Mr. Freyssinet has mentioned this special point, with good reason, in the *Génie Civil* of the 13 August 1921.

The second new feature, which, according to Mr. Leinekugel Le Cocq, also follows from the practical results obtained on railways since the war, is due to the introduction of selected materials. He shows that the use of high-tensile steels should be increased in large bridges, particularly at the present time when the high cost of labour for maintenance, working, carriage, erecting and riveting in place, are entirely functions of the weight and are independent of the quality of the metal used for the work. As the preceding factors are much more important than the additional expense involved by using special steels, the economic aspect of the question holds good.

From the point of view of oxidation in the open air, this is only an apparent obstacle, because, for equal strengths, the surfaces are reduced; moreover, the example of the past, and of the progressive change from iron having an allowable stress of 6 kgr. per mm² (3.81 English tons per square inch) then to ordinary mild steel with an allowable stress of 8 kgr. per mm² (5.08 English tons per square inch) subsequently carried to 10 kgr. and 12 kgr. 5 per mm² (6.35 and 7.95 English tons per square inch) show that there are no objections to this course.

With regard to the suspension bridge over the Rhine at Cologne, which was described in the *Génie Civil* of 4 December 1920, and in which part consists of mild steel, and part of 1 % nickel steel, Mr. Leinekugel Le Cocq remarks that the use of varied materials should be discouraged as far as possible in works of great size. Bearing in mind the technical knowledge now available, one cannot believe that large piers of great heights, for example, will be in future constructed as formerly of dressed stones for the angles and facings with filling of rubble and concrete.

Actually in making these piers, either completely of concrete, or with corners and facings suitably constructed in reinforced concrete, the central core being hollow, one is certain that the homogeneity of the structure will ensure equal and uniform distribution of the load, particularly if all the rules of the art are respected, and from this an economy in material and labour will be obtained.

In concluding, the author of the paper renders homage to the French engineers of the 19th century, who have evolved this wise conception of the appropriate utilization of the materials of their time. Amongst them he quotes, for example, the engineer of the great suspension bridge of Zaehringen at Fribourg over the Sarine (Switzerland).

This important bridge, designed and built in 1834, at the beginning of the period of construction of suspension bridges, by the French engineer Chaley, with a span of 265 m. 25 (870 ft. 3 in.) is still standing. Chaley used materials of the greatest strength then available with a suitable factor of safety, adopting iron wire, the drawing of which was commenced in France, with every success in 1820, as Seguin senior mentions in his paper read before the « Académie des Sciences » on 26 January 1824.

In the great Fribourg bridge the engineer Chaley adopted for number 18 (French wire-gauge) iron wires which had an ultimate tensile strength of 82 kgr. (52.07 English tons per square inch), a maximum applied force of 26 kgr. 90 (17.08 English tons per square inch). Thanks to this appropriate use of material he was able to construct this great work which deserves to carry his name down to posterity.

As Mr. Leinekugel Le Cocq states, this example, and many others of the same class, show well that, in order to make progress at any time, it is necessary that science should be intimately associated with the results of practice.

A. D.

[621 .33 (.45)]

The electrification of the Turin-Ciriè-valleys of Lanzo Railway with continuous current at 4 000 volts,

By A. S.

Figs. 1 to 9, pp. 1206 to 1211.

(Rivista dei Trasporti.)

Historical note. — The three valleys of Lanzo, which stretch into the Cottian Alps between the Susa pass and the Val d'Orco (Ceresole Reale), are favourite places with the inhabitants of Turin for holidays and excursions, both on account of their natural beauty and because they are near to the city. For a length of more than 30 km. (18.5 miles) they offer all the characteristics of medium and high mountainous country and are crossed by good carriage roads running up to 1 800 m. (5 906 feet) in height. The Alpine climber finds a great field for his sport, because the three valleys are closed by the chain of Alps that comprises such important summits as the Rocciamelone 3 538 m. (11 608 feet), the Croce Rossa 3 567 m. (11 703 feet), the Bessanese 3 632 m. (11 916 feet), the Ciamarella 3 676 m. (12 061 feet), the Levanna 3 619 m. (11 874 feet), and many others of less height.

The railway which runs through a region that is essentially industrial and agricultural had been carried as far as Lanzo in 1876, that is to say it went up to the commencement of the valleys; the distance from Turin to this point is 31.1 km. (19.3 miles). In October 1913 work was commenced on the new Lanzo-Ceres section of a length of 11.7 km. (7.3 miles) which was fully opened to traffic on 17 June 1916.

This section, which serves a mountainous and extremely picturesque region, presents remarkable features.

The passenger station buildings, all constructed in the same style and in proportion to the size of the stations, with their accessory buildings are adapted to harmonize with the beauties of their natural situation.

There are five tunnels; the shortest has a length of 66 m. (72 yards) and the longest 234 m. (256 yards).

There are also important bridges for crossing the Stura torrent, namely:

A bridge with four 17 m. (55 ft. 10 in.) spans and two 6 m. (19 ft. 8 in.) spans;

Two bridges each with two 17 m. (55 ft. 10 in.) spans;

A reinforced concrete bridge with a single arch 40 m. (131 ft. 3 in.) span and 3.90 m. (12 ft. 10 in.) sagitta;

A cement viaduct with one arch of 30 m. (98 ft. 5 in.) span, twelve of 8 m. (26 ft. 3 in.) and four of 6 m. (19 ft. 8 in.) span;

A large reinforced concrete viaduct 198 m. (649 ft. 8 in.) long consisting of a semicircular arch 50 m. (164 feet) span and a series of short spans.

On the new Lanzo-Ceres section there are no level crossings. The reinforced concrete work was carried out by the firm of Porcheddu of Turin.

The railway connects the city of Turin with the village of Ceres situated 700 m. (2 297 feet) above sea level and 42.8 km. (26.6 miles) from Turin.

The heavy passenger and goods traffic had at an early date caused the railway management to decide on the advisability of replacing steam traction by electric traction, and this change would have been effected at the same time as the extension to Ceres if the war had not caused the contract with the manufacturers to be suspended. The idea, however, was not abandoned, and, after several unsuccessful attempts to obtain the necessary financial support, it was finally possible, by increasing the capital from 2 300 000 to 10 million lire in 1918, to proceed with the execution of this important scheme.

Technical details of the installation. —The railway, which leaves Turin at a height of 225 m. (738 feet) above the sea level, rises the whole way except for a short length of 600 m. (656 yards) before kilometre 7 (mile 4.4) near Venaria Reale, which is a downgrade. The line may be divided into four sections as follows:

Turin-Ciriè: 20.2 km. (12.6 miles) long; average gradient, 8.3 per mil;

Ciriè-Lanzo: 10.9 km. (6.8 miles) long; average gradient, 12.7 per mil;

Lanzo-Pessinetto: 8.8 km. (5.4 miles) long; average gradient, 19 per mil;

Pessinetto-Ceres: 2.9 km. (1.8 miles) long; gradient, 35 per mil.

The line, of normal gauge, connects with the Italian State Railways at the Turin - Dora station; there are 10 km. (6.2 miles) of double track between Borgaro and Ciriè and single track for the remainder of the length.

On the Turin-Lanzo section, on which the curves have a minimum radius of 400 m. (20 chains), rails weighing 30 kgr. per metre (60.47 lb. per yard) of the F. S. O. II type are used; on the Lanzo-Ceres section with curves of a minimum radius of 200 m. (10 chains) the track is laid with rails weighing 36 kgr. per metre (72.58 lb. per yard) of the R. A. 36 S type.

Of the different methods available for electrification selection was finally made of continuous current at 4 000 volts; this method was adopted with the object of reducing the sub-stations to a single one for conversion and effecting an economy in copper while remaining within the normal limits for drop in voltage. This is the first instance of continuous current traction at so high a voltage. The installation which was carried out entirely by the Italian works of Brown-Boveri, in their Milan factory, was executed on the basis of the strictest economy possible without neglect of safety and of convenience in working.

Converter sub-station. — The sub-station was constructed at Ciriè, that is to say at about the middle of the line. It covers a superficial area of 483 m^2 (5 200 square feet) measuring 32.2 m. by 15 m. (105 ft. 8 in. by 49 ft. 3 in) and its contents are about 550 m^3 (19 424 cubic feet).

Energy is supplied by the Upper-Italy Electric Supply Co. Ltd, as three-phase current by means of one of two three-wire lines, at 22 000 volts, 50 periods. These lines come from Funghera in the Lanzo valley and run close to the sub-station. The switches are so arranged that the sub-station at Ciriè can derive its supply either from the hydro-electric generating station of Funghera, or from the steam generating station at Turin.

The energy supplied at 22 000 volts is reduced in the sub-station to 500 volts by means of two 800-kw. three-phase oil insulated transformers with natural cooling. A tapping at 250 volts from the secondary circuit is used to start the

synchronous motor of the converter group. The latter consists of a set of five machines arranged on a single shaft revolving at a speed of 1 000 revolutions per minute, that is to say: the synchronous three-phase motor in the centre; two dynamos in series on each side of the motor; and two exciters, one for the motor and the other for the dynamos, at the ends of the group.

The three-phase synchronous motor which is capable of developing 716 kw. continuously, is started as an asynchronous motor at 250 volts and cuts into 500 volts on attaining synchronous speed. The two dynamos coupled in series are each capable of developing 325 kw. continuously at a speed of 1 000 revolutions per minute and are capable of developing double this power for five minutes; they each generate current at 2 000 volts. They have four main poles and four auxiliary poles with independent and reverse compound excitation. The independent excitation is effected by the 60-volt exciter the excitation of which is regulated by a Brown-Boveri automatic regulator which tends to maintain a constant voltage; the reverse-compound excitation comes into play in case of short circuiting with the special object of protecting the dynamos against sparking. The exciter of the synchronous motor has, in its own field, some turns in series with the main circuit for the dynamos, so that when the load on the dynamos increases there is an automatic increase in the excitation of the synchronous motor so improving the load-factor of the system.

There are actually two converter groups in the sub-station, and provision has been made for the possible installation of a third.

On the continuous current switchboard are the automatic-voltage-regulators of the Brown-Broveri type and the maximum cut-outs with arc breakers (fig. 1), here adopted for the first time on high-tension continuous current. These cut-outs, shown diagrammatically in figure 2, are remarkable for the multiple and successive interruptions of the circuit with gradual insertion of resistances in such manner as to reduce the arc which would be formed on opening the cut-out proper. The latter, shown at I in the diagram, when opened controls the successive opening of three aluminium horn contacts 1, 2, 3, by means of a cam-shaft. The first two are shunted through the resistances r' and r'' so that, when I and the horns 1 are open, current passes through r', 2, 3; when the horns 2 are then opened, the current runs through r' r'', 3 and the circuit is finally broken on opening the horns 3.

The two contact lines leave the bus-bars at a pressure of 4 000 volts from earth, the one between Ciriè and Turin and the other between Ciriè and Ceres. An electro-magnetically controlled switch enables the resistances of the two sections of the line to be checked independently before the current is put on.

The three-phase plant is protected by means of small cylinder Wurtz dischargers and three-pole automatic maximum current cut-outs immersed in oil. The continuous-current portion is protected by kicking coils and horn-break dischargers. On each outward line there is an automatic maximum cut-out of the type described, and one of these is moreover fitted to each machine between it and the 4 000-volt bus-bars.

Contact line.— The contact line, which is of copper is of 60 mm² (0.093 square inch) cross-section; it is double for the railway section from Ciriè to Borgaro (10 km. [6.2 miles]) which is double track; on the railway section from Ciriè to Ceres a feeder has been installed between Ciriè and Lanzo (11 km. [6.8 miles]) of the same cross-section as the contact line to compensate for the drop in voltage on the upper section of the railway.

The line is suspended from wooden

Fig. 1. — Circuit-breaker.

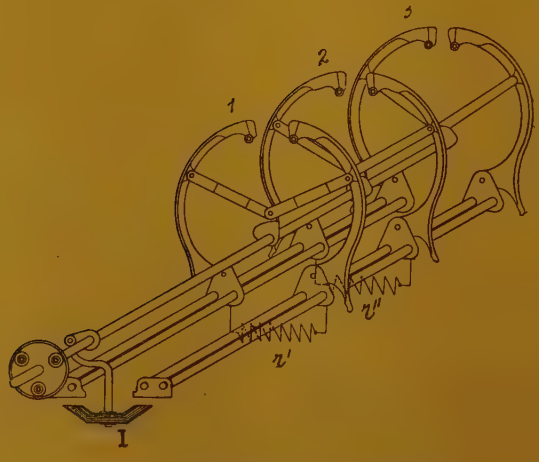


Fig. 2. — Diagram of circuit-breaker.

Fig. 3. — Suspension of overhead conductor on double track.

Fig. 4. — Suspension of overhead conductor on single track.

Fig. 5. — Lanzo Station.

Fig. 6. — Locomotive.

poles arranged 50 m. (164 feet) apart on the straight and 35 m. (115 feet) on the curves. After external charring the base they are buried in the ground surrounded by broken stone to a depth of about 1.70 m. (5 ft. 7 in.); their total height is 9.20 m. (30 ft. 2 in.) and they are protected at ground level by a block of cement, about a half-metre cube (0.654 cubic yard). They are, moreover, tarred for a length of 30 cm. (1 foot) above the block and at the top. Their diameter is about 35 cm. (1 ft. 2 in.) at the base and 20 cm. (7 $^{7}/_{8}$ inches) at the small end.

The suspension is of the simple catenary type, from a steel carrying cable 34.5 mm² (0.0535 square inch) in cross-section with suspension wires also of steel and is carried over the double-track (fig. 3) by steel wires across the tracks 6 mm. (0.236 inch) in diameter with a double row of posts; for the single-track line the same system is used for a portion of the length and a part is carried on channel-iron brackets (fig. 4). The suspension cable is supported from the brackets by means of a porcelain insulator of double-petticoat form with cap of cast iron. To avoid swaying of the contact wire this is kept in place by pull-offs carried on the posts and clips with double petticoat porcelain insulators.

In the stations the contact wire is held up without a catenary cable by means of steel wires across the tracks with insulated supports inserted at the points to which the wire is attached and with strain insulators at the anchorages of the cross-wires (fig. 5).

Close to each station there is a switch to enable the contact wire to be disconnected on the side of the rail head (that is, of the end of the railway line).

For the maintenance of the contact line a tower wagon driven by petrol motors is used.

Locomotives.— The locomotives (fig. 6) drive on all wheels and weigh 42 tons (41.3 English tons); they are carried on bogies with four independent driving axles. They are fitted with four motors of the ventilated series-traction type carried by stays attached directly to the casings, which are partly carried on the bolster and partly on the bogie frame through links suitably arranged with helical springs interposed.

The transmission is spur-gear having a reduction ratio of 1 : 3.95. Each traction motor is capable of developing 140 H. P. for one hour at a speed of 660 revolutions per minute and with 1 800 volts at the terminals (3 600 volts at the contact wire).

Each locomotive is fitted with two pantograph collectors, with bows fitted with aluminium shoes lubricated by means of grease contained in two grooves.

The body of the locomotive is divided into five compartments, that is to say: the two end compartments for the driver, a luggage compartment, a service gangway the length of the side frames, and the compartment containing the high-tension apparatus. The latter has a single door, locked by the pneumatic control-gear in such manner that it can only be opened when the bow of the current collector is lowered and when the automatic cut-out is open. The sides of the compartment are partially removable to facilitate the assembly and removal of the apparatus for inspection and maintenance.

In each of the driver's compartments there is a switch-board (fig. 7) by means of which the driver controls from a distance, mechanically and pneumatically, the appliances contained in the high-tension compartment, the raising or lowering of the pantographs, and the starting or stopping of the motor-compressor set. In this chamber there are, moreover, compressed-air brake apparatus, both automatic and variable, hand brake, sanding gear, measuring instruments, small switch-boards for auxiliary services and the speed indicators.

The high-tension electric appliances contained in the compartment are the controller with the arc-break; the main maximum current cut-out; the converter group for the auxiliary services with its cut-out; the starting resistances; the various additional resistances of the appliances and the switch for weakening the fields of the motors.

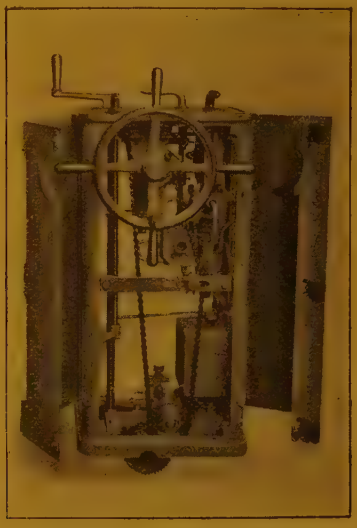


Fig. 7. — Control switch-board.

The controller, which is one of the more interesting features of the electric equipment, consists of two distinct parts: the controller properly so-called (fig. 8) and the circuit breaker. The two appliances are connected by means of a rigid and insulated joint in such manner that the rotation of the main cylinder involves the working of the breaker.

The controller is operated from the switch-board by means of chain-wheels and a central transmission running through the locomotive lengthwise. It consists of three cylinders; the main cylinder, that is the central one, is used in the connection scheme for obtaining the various speeds for series-parallel running and the electric braking of the traction motors; the two others, situated on each side of the main cylinder, are controlled independently and serve: the one for reversing the direction of running, the other for cutting a group of motors out of the circuit. The reversing cylinder is controlled from the operating switch-board by means of transmission gear and levers; the other cylinder can only be operated from the inside of the high tension chamber, and consequently after the bows have been lowered and then by means of a special lever.

The circuit breaker has been arranged to open the circuit gradually, and at numerous points in the same manner as already described for the cut-outs instead of at the controller contacts proper. It consists of six pairs of aluminium horns terminating with copper tips. The opening and the closing of these horns is effected by the rotation of the main cylinder and controller drum, the shaft of which, by means of the insulated joint, turns the shaft of the circuit breaker; the opening and the closing of the horn are adjusted by a set of eccentrics and levers; the arcs are then blown out by means of powerful magnetic blow-outs.

The main automatic cut-out is identical with those described for the converter sub-stations; *i. e.,* it is designed on the same principle of the multiple and successive interruption of the arc. That on the locomotives is usually pneumatically controlled; in case pneumatic control is impossible it can be operated from the outside of the high-tension compartment by a removable handle and a rigid insulated joint.

The convertor group for auxiliary purposes is also contained in the high-tension compartment and consists of two motors arranged in series, with a total output of 23 kw. each working at 1 800 volts, series-wound with 4 main and 4 auxiliary poles; the motors drive a 110-volt, 15-kw., dynamo to which they

Fig. 8. — Controller.

Fig. 9. — Motor G. D. T. M. 2 type.

are directly coupled. The group consequently reduces the high-tension continuous 4 000-volt current to low-tension 110-volt current for the lighting and heating circuits and for the compressor motor which is on the outside of the locomotive body and is hung from the main frame of the latter between the bogies.

The starting resistances, enclosed in a special casing, consist of cast-iron elements carried on porcelain insulators and arranged in an iron box. They are air-cooled by means of a fan keyed to the shaft of the convertor group described above. By suitable arrangement of the resistances twelve running speeds are obtained and seven variations of electric braking.

The traction motors are permanently coupled in pairs in series, with the possibility of arranging the two groups thus formed either in series or in parallel. The same starting resistances serve, except at the instant when the connections are changed for the seven speeds in series, for the five in parallel, and for electric braking with the motors short-circuited.

Apart from the twelve running speeds, obtained by the arrangement of the motors in series or in parallel and with the resistances cut-out, a still greater speed can be obtained by means of an arrangement for weakening the field of the motors. By means of a switch in the high-tension compartment, controlled pneumatically from the switch-board, a portion of the field of the motors can be cut-out in such manner as to obtain an increase in speed of about one-third of the corresponding speed for the full field.

The locomotive can develop a tractive effort at the drawbar of 4.65 tons at its hourly rating and a maximum drawbar pull for starting of 9.3 tons.

Dependent on the gradients of the line, the passenger trains have a total weight of about 150 tons on the Turin-Lanzo section and about 85 tons on the Lanzo-Ceres section and attain the speeds respectively of 65 and 45 km. (40 and 28 miles) per hour. The goods trains are run without shunting the motor fields and are of about 250 tons total weight on the Turin-Lanzo section and of 110 tons on the Lanzo-Ceres section.

Rolling stock. — The normal passenger service is worked by means of vehicles built by the Maschinenfabrik Augsburg-Nürnberg of Nuremberg (M. A. N.) in place of the old rolling stock which was not so well suited to the increased speeds. A portion, however, of the old rolling stock is still in present use.

The carriages of the M. A. N. type are at present eight in number; four mixed first and third class and four third class only; they have a length of 18.8 m. (61 ft. 8 in.) over the buffers and a total weight of 29 tons and are carried by two bogies with swing bolsters. The interior of the body is divided into four compartments and three corridors; two lateral and one central. There are 72 seats in the composite carriages and 80 in the third class carriages. The vehicles are fitted with independent electric lighting of the Brown-Boveri type, with a dynamo driven from the carriage axle, and a battery for use during stoppages and at speeds below 25 km. (15.5 miles) per hour. An automatic governor ensures the insertions of the lights at the proper moment, into the dynamo circuit or the battery circuit and maintains the pressure at 24 volts. The carriages have through communication by open gangways; they are warmed by means of heat accumulators that are heated up at the terminal station and they can also be supplied with current from the convertor group on the locomotive while travelling.

Cost of installation. — The total cost for the replacement of steam-traction by electric traction amounted to 5 699 339.60 lire

made up as follows: convertor sub-station 1 615 966.90 lire of which 433 779.45 lire were for the building; the contact line and the electric bonding of the rails 2 076 453.60 lire of which 549 649.30 lire were for the lines of poles; locomotives 1 860 000 lire; general expenses 146 919.10 lire.

These figures show to what extent the adoption of the high-tension continuous current system was justifiable, particularly in relation to the installation of the contact line and of the single sub-station. If the length of the electrified tracks is taken as 65 km. (40 miles) of which 53 are ordinary track and 12 in stations (32.5 and 7.5 miles) the cost of the contact line per kilometre of electrified track does not amount to 32 000 lire (the price of copper being taken on the basis of 10 lire per kilogramme).

Similarly, the cost of the central convertor station amounts to 25 000 lire per kilometre of electrified track and to about 1 100 lire per kilowatt installed.

In all, the cost of installation per kilometre of electrified track amounts to 88 000 lire, a figure which is relatively small when compared with other systems of electric traction, particularly when the advantages offered by continuous current in working are taken into consideration.

First results of working. — The first locomotive was put into service on the 6 October 1920 and the others followed between October 1920 and April 1921 as shown by the table below which gives the distances in kilometres (in miles) run by the locomotives in each month of the financial year ending in August 1921.

LOCOMOTIVES.	1920			1921								TOTAL.
	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	
I . . .	4 220 (2 622)	3 049 (1 895)	4 560 (2 834)	5 610 (3 486)	5 984 (3 718)	5 662 (3 518)	5 211 (3 238)	5 820 (3 616)	5 972 (3 711)	6 032 (3 748)	6 309 (3 920)	58 429 (36 306)
II . . .	...	504 (313)	3 314 (2 059)	6 783 (4 215)	5 083 (3 159)	6 584 (4 091)	5 776 (3 589)	4 023 (2 500)	5 068 (3 149)	3 740 (2324)	6 576 (4 086)	47 451 (29 485)
III . . .	...	...	444 (276)	6 166 (3 831)	6 634 (4 122)	5 346 (3 322)	5 398 (3 354)	5 270 (3 275)	2 558 (1 589)	4 164 (2 587)	6 210 (3 859)	42 190 (26 215)
IV . . .	...	...	...	...	526 (327)	6 178 (3 839)	4 707 (2 925)	5 358 (3 329)	6 964 (4 327)	5 794 (3 600)	2 200 (1 367)	31 727 (19 714)
V . . .	...	...	...	...	...	...	1 292 (803)	4 876 (3 030)	6 041 (3 754)	7 114 (4 421)	7 282 (4 525)	26 605 (16 533)

The table shows how great a distance is run by the locomotives and consequently how well they have come up to expectation. It is to be noted that a small staff ensures good maintenance, its duty being to examine, after each trip — a distance of about 90 km. (56 miles), the main details, such as the controller, the auxiliary-service group and the pantograph bows. A rapid general examination is made daily of the various parts and a complete inspection is made every fortnight of the traction motors without taking the parts down; this inspection deals mainly with the commutators, brushes and brush holders. A complete inspection is also made every fortnight of all the high-tension apparatus and of

the lubricating gear and at the same time the oil is renewed in the bearings of the auxiliary service group and in the main bearings of the traction motors.

The contact line and converter sub-station have run up to the present without any failure as it has been possible to deal quickly with the ordinary difficulties arising in service.

The drop in voltage over the ends of the railway line, estimated at 15 %, has remained inside this limit in each case with trains made up as stated above.

The most important problem arising with high-tension continuous current operation is in the breaking of the arcs formed by opening the circuits. It has been solved, as has been explained, and the solution has answered all that was required, both in the sub-station and on the locomotives, so satisfactorily that up to the present there has been no complaint of difficulty due to defective working or to inherent defects in the apparatus for causing the breaking of the arc.

The commutators of the traction motors have stood perfectly up to the present and are still in perfectly good order, although some have already done more than 50 000 km. (31 000 miles) without being turned in the lathe.

Inductive effects on the telegraph and telephone circuits. — It is a matter of general knowledge that apart from many other advantages continuous current does not give rise to induction effects of sufficient magnitude to cause difficulty in practice in the telegraph and telephone circuits. In the installation in question the conditions are such as to be best suited for showing this advantage.

The State line of telegraph and telephone poles runs the whole length of the railway line from Turin to Ceres, and, apart from these, it also carries the general telegraph circuit and the double wire telephone circuit recently installed for the working of the railway. These latter two lines run from Turin to Ceres, with branches at the stations. As far as Germagnano, that is to say for 33 km. (20.5 miles) the telegraph and telephone poles run parallel to the road-bed of the railway, the distance of the telephone wires from the contact wire varying between 5 and 8 m. (16 ft. 5 in. an 26 ft. 2 in.). In the mountain section from Germagnano to Ceres the telegraph line follows a different route to the railway, approaching it at many places and receding in others according to the configuration of the ground. Notwithstanding the short distance from the contact wires on the first section of 33 km. (20.5 miles) there has been no complaint from the telegraph and telephone services of disturbance due to induction.

An opportunity of confirming this advantage occured recently on installing the railway telephone system by means of which communication is made between Turin and Ceres; there has been no disturbance of the receiving apparatus due to starting and to the frequent variations in load on the contact wire caused by the traction demands.

Commercial efficiency of the service. — The table below shows the total consumption of three-phase energy and also the consumption of continuous current per ton-kilometre.

It shows clearly how the consumption and efficiency have improved simultaneously as the working conditions have become more nearly normal. Steam traction was completely abolished on the line on the 17 March and the total traffic (which had previously been decreasing for goods) began to increase from the 16 May 1921.

For calculation of the length of the line, the formulæ in use on the State railways have been used as the basis for comparison. It should be noted, however, that on the Turin-Ceres railway, that is to say, for a distance of 43 km. (26.5 miles), seventeen starts have to be

made on gradients so that the consumption of continuous current in watt-hours per virtual ton-kilometre is actually less than that given in the table.

YEAR AND MONTH.	Kilowatt-hours of alternating current.	Kilowatt-hours of continuous current	Efficiency of the sub-station.	Total ton-kilometres (total English ton-miles)		Watt-hours (continuous current):	
				Actual.	Virtual.	per actual ton-kilo-metre (per actual English ton-mile).	per virtual ton-kilo-metre (per virtual English ton-mile).
1920							
October	43 345	26 200	61.9	569 075 (348 028)	853 612 (522 042)	46.1 (75.4)	30.8 (50.4)
November	32 895	19 900	60.5	421 708 (257 903)	632 762 (386 977)	47.2 (77.2)	31.4 (51.3)
December	79 515	47 300	59.5	1 048 507 (641 234)	1 593 731 (974 675)	45.2 (73.9)	29.6 (48.4)
1921							
January	123 770	88 900	71.9	1 956 451 (1 196 503)	2 973 805 (1 818 685)	45.5 (74.4)	29.9 (48.9)
February	123 200	91 500	74.3	2 097 663 (1 282 864)	3 088 447 (1 888 796)	43.7 (71.5)	28.9 (47.3)
March	165 535	123 400	74.5	2 840 059 (1 736 890)	4 330 563 (2 648 435)	43.3 (70.8)	28.5 (46.6)
April	157 010	117 400	74.8	2 727 418 (1 668 002)	4 145 675 (2 535 363)	43.7 (71.5)	28.9 (47.3)
May	162 191	126 660	75.5	2 917 648 (1 784 341)	4 434 410 (2 711 945)	43.4 (70.9)	28.5 (46.6)
June	168 865	129 300	76.6	2 964 441 (1 812 958)	4 565 767 (2 792 278)	43.6 (71.3)	28.4 (46.4)
July	177 631	135 400	76.4	3 207 521 (1 961 618)	4 960 144 (3 033 467)	42.3 (69.2)	27.3 (44.6)
August	192 177	147 400	76.6	3 502 671 (2 142 123)	5 471 351 (3 346 105)	42.1 (68.8)	27 (44.1)
September	181 095	138 900	76.7	3 451 436 (2 110 789)	5 339 389 (3 265 401)	40.3 (65.9)	26 (42.5)

From the data relating to the consumption during the first months of working, it is easy to establish comparison between an item in the cost of steam traction and the corresponding item in the cost of electric traction; for example, between the expenditure on coal and the corresponding expenditure on electric energy. In 1920 the total consumption of coal per actual ton-kilometre was 0.115 kgr. (0.415 lb. per English ton-mile): this high figure is evidently explainable by the use of locomotives which had not undergone general overhaul since the commencement of the war. Assuming a basic price for coal of 250 lire per ton,

a price which has not been reached so far for good steam coal, the total cost for fuel per actual ton-kilometre amounts, in the case of steam traction, to 0.0287 lira.

The first results of working with electric traction show a consumption of the energy in alternating current of 0.057 kw.-h. per total actual ton-kilometre (0.093 kw.h. per total actual English ton-mile). With the rates at present in force the mean annual cost of alternating current is 0.13 lira per unit. At this rate the cost of energy per total actual ton-kilometre with electric traction amounts to 0.0074 lira and it is in the ratio of 1 to 3.86 of that for fuel. This ratio is approximately constant because by the terms of the contract with the suppliers of energy the cost of this varies with the price of coal.

Assuming that the sinking fund is based on the mean rate of five per cent, that is to say in twenty years, for the whole cost of the electric installation, but taking account of the fact that the whole of the mechanical rolling stock for steam traction has been completely written off, and supposing that the cost of working is the same in both cases, — though actually less in the case of electric traction, — the ratio above of 1 : 3.86 then becomes 1 : 1.85 or in other words the advantage is still appreciably in favour of electric traction.

Conclusion. — The results of some months of working enable it to be stated that the use of high-tension continuous current for traction on railways in its first practical application on this Italian railway (and the first application in the world if the fact is taken into consideration that the 5 000-volt trial in America was only a temporary one) has been satisfactory and encouraging. Economy in installation and working, safety of operation of the electric apparatus, simplicity and lightness of the overhead line, the avoidance of disturbing effects on the telegraph and telephone lines, the well-known characteristic features of the series-traction motor running with continuous current, and the ease of control when running, are absolutely indisputable advantages.

To sum up, the results obtained on the Turin-Ciriè-Valleys of Lanzo line may be considered as thoroughly favourable and it may safely be predicted that high-tension continuous current will be applied without delay to heavy traction because those difficulties which were previously considered serious, and prevented the adoption of the system, have now been tackled and surmounted.

The other difficulties which will be encountered in an extension of this solution to still larger powers appear, so far as can be ascertained, to be of similar nature to the difficulties already encountered, and to be capable of being tackled with complete confidence by the designers, by the constructors and particularly by those who recognize in this field the absolute necessity of effecting a proper compromise between technical improvements and commercial results.

[625 .113]

Railway curves : Superelevation and maintenance,

By E. E. R. TRATMAN.

Figs. 1 and 2, p. 1225.

(*Engineering News-Record.*)

In railway practice, curves have not only an important relation to location but a still more important relation to operation and maintenance, since they introduce complications regarding train resistance, load, speed and safety, while they are also the direct cause of increased cost and work in track maintenance. Much improvement has been effected during recent years in reducing the amount of curvature and eliminating specially sharp curves, but this work has applied largely to excessive or extreme conditions and has not reduced the problems of curve maintenance and operation to any great extent.

It has been estimated that under ordinary traffic conditions the operating cost is increased by $1 per degree of curvature per daily train per year, and that each 12 degrees of curvature per mile adds 1 per cent to the labor cost of maintenance. These prewar figures would be too low at the present time, but they serve to indicate the financial relation of curvature to operating and maintenance. Wear and maintenance expense are assumed generally to increase directly with the central angle of curve, but investigations noted in the *Proceedings of the American Railway Engineering Association* for 1919 (p. 754) indicate that they increase as the square of the curve.

As compared with tangent track there is greater wear and displacement of rails, fastenings, ties and ballast, due to the lateral pressures exerted by the wheels, so that track material has a shorter life and maintenance work is required more frequently. Further, there is the problem of keeping curves in such condition that fast passenger trains will ride easily around them and slow freight trains will not be subject to excessive curve resistance.

Various aspects of railway curves in relation to train operation and track maintenance are dealt with in the present article, with a review of variations in practice as illustrated by information from a number of railways.

Curve elevation, or the superelevation of the outer rail on curves, is introduced to counteract the centrifugal force of trains, to relieve the rails of wear and lateral pressure, and to give a safe and easy riding movement of trains passing through the curve. But as centrifugal force varies with the speed, and trains of various speeds traverse the curve, the adjustment of superelevation to suit both high and low speeds must be a matter of compromise. Practice in the superelevation of track curves is based largely on old time theories and tests, modified by experience under modern conditions, so that in many cases it is little more than « rule of thumb ».

Since the amount of elevation for any specific conditions of speed and curve may be determined by calculation, the matter is apt to be regarded as a definite mathematical problem capable of being solved by established formulas. In fact, recent inquiry as to whether present

practice is satisfactory brought some replies to the effect that established formulas are as applicable now as at any previous time, since they are based upon scientific principles which do not change. One reply stated specifically that the rules are entirely efficient and satisfactory for present locomotives and present train speeds because: « the superelevation is governed by the correct mathematical formulas and it is the speed which governs the superelevation. »

Theoretically this is true, but the problem is affected by many practical conditions and by the existence of varying conditions at any one point, so that mathematical solution at best can be no more than a guide or indication. That this is the case is evidenced by the variety in practice as to superelevation, by the changes made from time to time in an attempt to obtain better results, and by numerous examples of unsatisfactory experience.

Speed is one of the governing factors in the calculation of superelevation. But no curve is operated under conditions of a single rate of speed, since fast passenger trains, local passenger trains, tonnage freight and slow drag freight trains may all operate on the same track, and perhaps in both directions on that track. There is no rule or principle or line of scientific reasoning by which the most economical and suitable superelevation can be computed when diversity of traffic and variable speed enter into consideration.

In direct opposition to the views quoted above endorsing the sufficiency of mathematical solution of the problem is the following statement by the engineer of a large road: « Speed of trains being the principal factor in determining the proper superelevation it is impossible to arrange the track to meet all conditions of traffic. For this reason we do not adopt any universal practice on a theoretical basis, but treat the matter in a practical way based on experience in order to secure the best results under the varying local conditions. »

Multiple tracks which provide for separation of fast and slow trains and of passenger and freight traffic will simplify the conditions. But such trackage exists on only a small proportion of the railway system, and even there the variable conditions are merely reduced and not eliminated.

Where passenger traffic is the more important, a high speed factor may be used, but even so, the elevation must be limited to an amount which will not injuriously affect freight trains. Further, the location of the curve may enter into consideration. Thus, even on a double track high-speed line, the actual speed on a curve near the top of a long grade or near a station will be considerably lower than on a curve located along level ground or on a descending grade. A derailment due to elevation too low for the speeds allowed was noted in *Engineering News-Record*, 26 February, 1920, p. 433.

From these brief statements as to actual physical and operating conditions, it is evident that the selection of superelevation for any particular curve must be necessarily a compromise, and that judgment based on observation and experience is fully as important as the mathematical calculation which may support this judgment. One of the great difficulties for men in charge of track and maintenance of way is the selection of a compromise figure which will give reasonably satisfactory results under extreme or opposite conditions.

Length of engine wheelbase is not a factor in the mathematical calculation, but it has proved to be a troublesome factor introduced in some cases by new equipment. Although most of the engineers whose opinion was asked have replied briefly to the effect that the rules are satisfactory in regard to modern equipment, two cited difficulties arising from the use of new and large locomo-

tives, as noted later. It seems probable that further and more detailed inquiry would result in showing that similar difficulties have been experienced on many individual divisions or engine districts. Further, with heavier locomotives the wear and maintenance will be increased.

That superelevation tends to be in excess of the amount needed is indicated by several replies, some engineers advocating marked reductions from present practice. Another practical condition noted is the tendency of speed to increase with superelevation. In other words, on a curve elevated for a certain speed, enginemen who find that their trains ride easily are apt to increase the regular speed. Higher speed being noted by the track officials, increased superelevation is introduced. Slow orders or speed restrictions may be issued but it is useless to burden the engineman with many such orders, and it is obvious that these are not and cannot be obeyed with any exactitude in train service by night and day, in clear weather and in storm.

In relation to this matter of the sufficiency of present rules for curve elevation, inquiry was made as to recent studies of their efficiency under modern conditions of equipment and traffic. The most definite replies were to this effect : There has been no intelligent or thorough study or analysis of the present situation, and there are no recent reliable data on the subject.

No recent tests or investigations are noted by any railway, but reference is made to textbook formulas and to the routine observations as to the riding qualities and rail wear of curves. Nor do any roads contemplate changes in their practice, according to the replies to a specific inquiry on this point.

Lack of uniformity in opinion and practice is shown clearly by a study of the curve elevation rules and tables used by a number of railways, all these lines operating both fast and slow trains. From this comparison it is apparent that for the same given conditions of speed and curvature there are variations of from 50 to 100 % in the superelevations specified.

Of twenty-four railroads, nineteen issue tables giving the superelevation for different combinations of curve and speed; one uses a diagram, several give formulas and two use a system of ordinates. Only two state that they follow the recommended practice of the American Railway Engineering Association but others practically conform to it. Where a table is issued it is almost invariably for general application, but at least one road has a series of tables adapted to the conditions of different divisions or portions thereof.

Examples of the variations in practice, as shown by several tables, are given below :

A. *Range in curvature.*—As a rule the list of curves begins with 1 degree and increases by 1 degree increments, but in some cases it begins with 0.5 degree. In several tables there are half-degree interpolations for the flatter curves and in a few cases these interpolations vary by quarter-degrees. Two roads carry the table only to 8 degrees, three carry it to 12 degrees, four to 15 degrees, five to 20 degrees, and one each to 25 and 30 degrees.

B. *Range in speed.*—The speeds listed in the superelevation tables show a wider difference than the curvature, the number of speeds given ranging from five to thirteen. Usually they begin with 10 or 15 miles per hour, sometimes 20 or 30 miles per hour on large trunk lines, and continue by increments of 5 or 10 miles per hour to a maximum of 60, 75 or 80 miles per hour. In one case the limit is 100 miles per hour, but this is on the diagram mentioned above and is merely an arbitrary limit for plotting the diagram, since this is not specially a high-speed road.

C. *Range in increase of elevation.*—Of sixteen railroads, six increase the elevation by increments of 1/8-inch, six by 1/4-inch and four by 1/2-inch. In the first case the tables are lengthy, since there is a change with nearly every increase of curvature, but where the larger increments are used the same superelevation applies to groups of curves. In view of the extreme variation of actual speeds at any one curve, it is a question whether the 1/8-inch variation is necessary or useful. Further, doubt has been expressed as to whether such close measurement or refinement is maintained in actual practice. On the other hand it is included in the recommendations of the American Railway Engineering Association.

D. *Range in maximum elevation.*—In maximum superelevation prescribed, the range is from 6 tot 9 3/4 inches. A number of roads use 6 inches for 25 miles per hour on 15 degree curves to 60 miles per hour on curves of 3 or 4 degrees. Two roads use 7 inches for 45 miles per hour on 5 degree and 55 miles per hour on 4 degree curves. Four roads use 8 inches for 40 miles per hour on 8 degrees, 50 miles per hour on 5 degrees and 70 miles per hour on 2 1/2 degrees. Two roads specify 9 inches for 40 miles per hour on 8 degrees and 80 miles per hour on 2 degrees. Finally, one specifies 9 3/4 inches as its maximum, this being for 75 miles per hour on 3 degree curves. The American Railway Engineering Association gives 9 1/2 inches for 60 miles per hour on 4 degree curves, but recommends that « ordinarily an elevation of 8 inches should not be exceeded ».

With all allowance for difference of speeds, loads, grades and operating conditions on different railways, these wide variations in maximum limit of superelevation appear to indicate divergent opinions rather than scientific deduction or operating necessity. Some roads specify that where speeds are such as to require elevations (as determined by rule) in excess of the prescribed maximum, the speeds must be reduced. It is of interest to note here that several engineers consider present elevations are excessive, but this applies to the ordinary run of cases rather than to those which require the maximum elevation.

Summary of variations.—To illustrate more clearly the extreme range of practice in regard to superelevation under similar conditions, the accompanying table has been prepared from the tables issued by fifteen railroads. This table shows the range of elevations prescribed by different roads for the same combinations of speed and curvature. The figures in parentheses indicate the number of different elevations for each combination.

Table of variations in curve superelevations.

Speed, in miles per hour.	1 degree. — Inches.	3 degrees. — Inches.	5 degrees. — Inches.	10 degrees. — Inches.	15 degrees. — Inches.
20	1/4 and 1/2 (2)	1/2 to 1 (4)	1 to 1 1/2 (4)	2 to 3 (5)	3 to 4 3/4 (6)
30	3/8 to 1 (5)	1 1/4 to 2 (4)	2 to 3 1/4 (4)	4 1/8 to 6 1/4 (6)	. .
40	3/4 to 1 1/4 (4)	2 3/8 to 3 1/2 (6)	4 to 5 3/4 (5)	6 to 8 1/8 (2)	...
50	1 to 2 (6)	4 to 5 1 4 (5)	6 to 8 3/4 (4)	. .	...
60	2 to 2 1/2 (3)	6 to 7 1/2 (4)	. .	...	...

For example, for a speed of 40 miles per hour on a 5 degree curve, there are no less than five amounts of superelevation prescribed, ranging from a minimum

of 4 inches to a maximum of 5 3/4 inches. These several amounts are 4, 5 1/8, 5 1/2 and 5 3/4 inches. For 30 miles per hour on 10 degree curves, these fifteen railroads have six different elevations, ranging from 4 1/8 to 6 1/4 inches. Further, for such easy conditions as 30 miles per hour on a 1 degree curve, there are five different elevations ranging from 3/8 to 1 inch. As noted above, it is probable that on different curves for which a theoretical elevation of 3 1/8 inches is prescribed, the actual elevations on individual curves will be more nearly 3 inches or 3 1/4 inches. For side tracks, maximum elevations of 1 inch and 2 inches are specified.

The string and ordinate system of determining superelevation is prescribed by two roads, according to the following rule: « Superelevation of outer rail on curves shall be the length, in inches, of the middle ordinate of a string or chord equal in length to the distance, in feet, traversed in one second by the average express train. » The elevation must not exceed 8 inches in one case and 7 1/2 inches in the other. Other roads also specify this method for cases where the degree of curve is not known, the chord lengths prescribed in two cases being as follows:

32 feet for 20 miles per hour;
40 — — 25 — — ;
48 — — 30 — — ;
56 — — 35 — — ;
64 — — 40 — — ;
72 — — 45 — — ;
80 — — 60 — — .

Here again there is diversity of practice. One road specifies the middle ordinate of a 60-foot chord or twice the middle ordinate of a chord of 43 ft. 8 3/4 in. Another varies the rule according to class of track, as follows : 1° Main passenger tracks, curves under 2 degrees to have an elevation twice the middle ordinate of a 62-foot chord or string, adding 2 inches to this amount for curves of 2 degrees and over; 2° main freight tracks, three-fourths of the ordinate as above; 3° combination tracks, the full length of middle ordinate.

Four formulas for determining superelevation on curves are given by different railways. In each of these as given below, E = the elevation in inches.

1. $$E = \frac{S^2 \times D}{1\,450},$$

S is speed in miles per hour, D is degree of curve and 1 450 is a constant.

2. $E = 0.00066\ DV^2$, where D is degree of curve and V is speed in miles per hour. Three roads use this, and it is recommended by the American Railway Engineering Association for ordinary practice.

3. The same as No. 2 but with 0.0007 as the figure.

4. $$E = \frac{GV^2}{32.2R}.$$

Here G is distance between centers of rails, V is speed in feet per second, and R is radius of curve in feet.

On curves having spiral easements or transition curves at the ends, the superelevation is made gradually on the spiral, so as to reach full elevation at the main curve. In some cases it is provided, however, that where the length of spiral is insufficient for this, the superelevation may be divided equally upon the tangent and spiral, or simply extended as far as necessary on the tangent.

For compound curves, other than spirals, it is usual to prescribe full elevation on the entire length of the main curve or curve of greatest degree, and then to reduce the elevation gradually to the amount required for the curve of less degree. While one road says simply that this reduction is to be made « gradually », others specify rates of 1/2 inch in 30 feet, 1/2 inch in 33 feet and 1 inch in 40, 60 or 67 feet. If a spiral is used

in connecting the two parts of a compound curve, the reduction must be made on the spiral. Such spirals are required by some roads when the change in rate of curve exceeds 1 degree or 2 degrees. In one case, the length of this spiral is required to be such as to increase the superelevation at the rate of 1 1/4 inches per second for the speed for which the curve is elevated.

For simple curves, without transitions or spiraled ends, the practice on twenty-two railroads is to give full elevation for the entire length of the curve, and to run it out to normal elevation on the tangent. Two roads provide for only half the elevation at PC and PT, the runout being divided equally upon the curve and tangent with a rate of 1 inch in 60 feet. In general, the rate of runout is 1/2 inch per 33 feet or per rail length, but some roads vary this from 1/2 inch to 1 inch, according to speeds. Other specified rates are 1 inch in 40, 50, 60 and 75 feet. Still others are as follows :

a) Runout varies as degree of curve and cube of speed; 100 feet for 50 miles per hour and 1 degree curve;

b) Runout 50 feet long for 1 inch elevation and increasing by 50 feet to 300 feet for the maximum 6-inch elevation;

c) Up to 3 inch elevation the runout is 1/4 inch per 30 feet; for higher elevations the length is not to exceed 360 feet;

d) Rate of runout equals 1 1/4 inch per foot per second, taking the velocity in feet per second for which the curve is elevated.

Runout for spiraled curves has been noted above under the heading « Spiral and Compound Curves ».

A difficulty which, as a rule, must be overcome arbitrarily and to suit local conditions, is that of providing runout for superelevation of reverse curves or of curves separated only by short tangents. Reverse curves in main track are prohibited by some roads. To eliminate the condition of short tangents, one road has made a point of substituting one long curve for two short curves or of separating the curves so as to provide each with suitable spirals and corresponding runouts.

In one case the rule is to divide the short tangent into two parts, in proportion to the degrees of the curves which it connects, the longer portion being adjacent to the sharper curve. At this dividing point the track is level transversely and the runout is made in each direction, extending onto the curves as far as may be necessary. The rate of runout varies from 1/2 inch in 30 or 33 feet to 1 inch in 30, 40 or 50 feet. For reverse curves, having no intermediate tangent, the runout is made in both directions from the point of reverse. Some roads reply simply that such conditions are matters for local study, or that superelevation is reduced in order that a proper runout can be secured. Two rules mentioned are as follows :

a) Between curves provide a stretch of level track equal to the length of the longest passenger car. A modification of this rule provides a fixed length of 30 feet;

b) When both curves are in the same direction, maintain the superelevation on the short tangent.

For individual curves the superelevation is prescribed usually by the engineer of maintenance of way, division engineer or roadmaster, due regard being given to the speed of trains, the adjacent profile and alignment and the local operating conditions. The necessary instructions are then given to the section foreman, who sometimes is provided with a list of all curves on his section, showing their degree and superelevation.

The difficulty of thus selecting the elevation which will best suit the particular curve is indicated by the fact that several railways issue instructions

to the effect that if there are indications of excessive or insufficient elevation, the necessary adjustment in elevation of rail or speed of train will be recommended by the roadmaster or engineer. Instructions as to changes in elevation made necessary by alterations in train schedules or speeds are issued by the engineers. In many cases a record of the approved superelevation on all main track curves is kept by the engineering department.

Assuming a satisfactory elevation to have been selected and properly applied to a curve, it soon becomes subject to modification under the influence of traffic and the settlement of ballast and roadbed. Both the alignment and superelevation may in time become more or less out of true, in spite of occasional checking and even if the curve is monumented or marked by line and elevation stakes. Maintenance of line and elevation on curves is left mainly to the roadmasters or supervisors, who examine the curves occasionally. In some cases they are provided with cords of certain length and are supposed to check curves frequently as to their uniformity by means of ordinate measurements. This is held to be sufficiently accurate under ordinary conditions, uniformity in line and superelevation being one of the main requisites for easy riding curves. All roads require observations of curves to be made by roadmasters or engineers traveling over their divisions on trains and noting points where the trains do not ride smoothly. In most cases, it is the aim to keep the elevation as low as will give an easy riding track for passenger trains.

Rail wear is usually a factor in determining the superelevation in maintenance work. But increased rail wear may be a normal result of larger and heavier engines (as noted later), so that excessive elevation may be introduced if this traffic condition is not taken into account. A tendency to excessive elevation in maintenance work is noted particularly by one railroad. Thus, as soon as the elevation is put up so as to make an easy riding curve it is found that enginemen will increase speed, which in turn leads to further increase in elevation. On some portions of the line this condition made it necessary to restrict the elevation to an arbitrary limit of 3 or 4 inches.

Engineering inspection and checking of curves is carried out to some extent by the engineering department, but in general this applies to individual curves where excessive rail wear or rough riding of trains indicates that attention is needed. One maintenance engineer expresses the opinion that the engineering department should specify the amount of superelevation, should mark this elevation at the curve and should check the curve at intervals of six months. A longer period might suffice where curves are adequately marked, as noted later, but it does not appear that any road follows such a systematic checking.

Survey and resetting of curves by engineers is done usually under two conditions only : 1° when improvement work is being carried out, such as rail renewal, reballasting or surfacing; 2° when a curve rides badly and the track forces seem unable to adjust it properly, so that the superintendent, roadmaster or local maintenance engineer calls for relining and staking of the curve.

In view of the development in weight and wheelbase of locomotives an inquiry was made as to whether present rules and practice in curve superelevation are proving satisfactory with modern equipment. Most of the replies were in the affirmative but were evidently rather perfunctory. Two exceptions throw a different light on the matter and suggest that other cases of unsatisfactory experience may be found on individual divisions or portions of railway systems. One of these unfavorable replies was

simply to the effect that the rules give superelevation which is excessive for certain new engines, so that it has been necessary to reduce the elevation materially in order to avoid derailments.

Another reply is more specific and points strongly to the locomotive as a present factor in curve elevation. On a division having rather crooked alignment and handling a considerable number of heavy freight trains, new engines of the 2-8-2 type, with a wheelbase of 21 to 22 1/2 feet gave considerable trouble on curves of 6 degrees owing to a tendency of the leading driving wheel to lift from the rail. The curves had been elevated for passenger trains, up to a maximum of 7 inches. The new freight engines were supposed to traverse curves of 8 degrees with gage widened 1/4 inch but in order to operate them it was found necessary to reduce the elevation about 50 % on curves of 4 to 8 degrees and to limit the maximum elevation to 5 inches. As freight traffic was the more important, « slow » orders were issued to reduce passenger train speeds at the troublesome points from 50 miles per hour to 30 or even 20 miles per hour. These engines would not curve freely enough to take No. 8 turnouts at terminals, where the curve was about 9 1/2 degrees, as the driving wheels would spread the guard rails or the trucks would get on the wrong side of the frogs.

It is almost universal practice to keep the low or inner rail at grade, and to raise the outer rail to full elevation. An earlier but limited practice of lowering the inner rail by half the amount and raising the outer rail equally, thus keeping the center line of track at grade, appears to be obsolete. Two exceptions are noted to meet special conditions. On double track, one railroad raises the outer rail of the outer track and depresses the inner rail of the inner track, in order to maintain the same level for the rails adjacent to the center line of roadbed. In another case, junction curves leading from the outside of main line curves, have the inner rail dropped in order to obtain the effect of superelevation on the turnout.

At main line junction curves, superelevation of the outer rail through the turnout or beginning of curve is impracticable, owing to the frog intersection of the curved lead rail and main line tangent. It is usual practice, therefore, to issue slow orders or speed restriction limits for such points and to use a turnout curve which will be satisfactory for these speeds. Two roads report special arrangements at such curves; one begins superelevation of the outer rail at the heel of the frog and the other lowers the inner rail of the turnout when practicable.

For junction turnouts, frogs of No. 14 to No.20 are used in general, corresponding to curves of 3 and 1 1/2 degrees respectively. The former is considered satisfactory for speeds not exceeding 20 miles per hour and the latter can be traversed at speeds up to 30 miles per hour without discomfort to passengers. Recommendations of the American Railway Engineering Association give limits ranging from 9 miles per hour for a No. 4 frog and 11-foot switch rail to 40 miles per hour for frogs Nos. 16 to 24 with 33-foot switch rails.

Unless curves are permanently referenced or monumented and are checked occasionally from the monuments, the actual curve is likely to vary from the original or true location, due to shifting under traffic and rectification by the section forces. This permanent marking assists the work of maintenance and also the future adjustment or resurvey.

The monumenting consists in placing permanent stakes to indicate the beginning and end of curves and the change from spiral or compound curve to the main circular curve. The center line may also be staked permanently and it is a general practice to set posts showing the amount of superelevation. But the

monumenting and marking of line and elevation are practiced systematically by relatively few railroads, and nine out of twenty-seven important roads report that they do not follow either method. Of the others, some mark line only or elevation only, while the remainder mark both and set curve monuments with more or less completeness. Some roads are introducing monuments and marks where curves are resurveyed.

Monuments consist usually of pieces of rail, iron stakes or wood posts placed outside the track and opposite the points of curve, spiral and tangent. On a few roads they are set also at intermediate points, as at 500-foot intervals.

For marking alignment, center line stakes are placed generally at these same points, and sometimes at intervals of 50 feet on the main curve and 25 feet on spirals, as indicated in figure 1. Iron

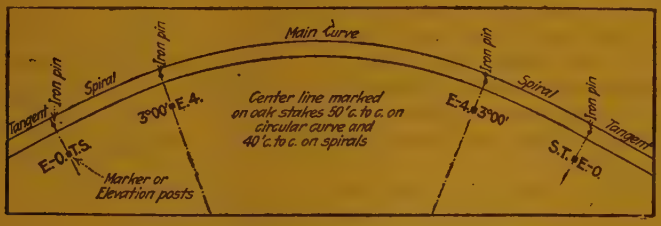


Fig. 1. — Monumenting and marking curves.

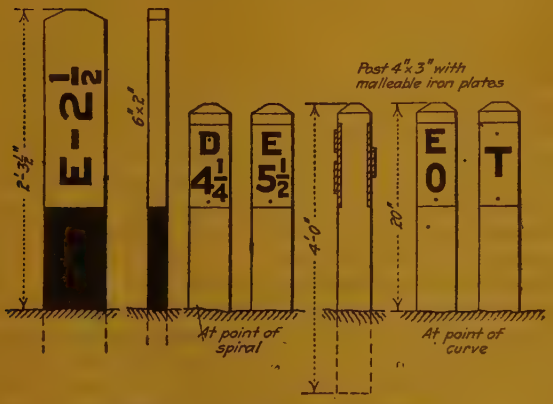


Fig. 2. — Curve elevation posts.

pins 1 1/2 or 2 inches in diameter and 3 1/2 to 4 feet long are most commonly used for this purpose, but splice bars and oak stakes 2×2×24 inches are employed in some cases. A few roads use stone posts 6×6×36 inches and one of these roads specifies them for use in all slag ballast. Chisel marks on the iron and stone stakes and tacks in the wood stakes should mark the exact center line.

Instead of the usual terms PC and PT, one road has adopted the following nomenclature for points on curves, indicating the change as each point is approached : TC, from tangent to curve; CT, curve to tangent; TS, tangent to spiral; SC, spiral to circular curve; CS, circular curve to spiral; ST, spiral to tangent; CC, curve to curve (on compound curves).

Many roads follow the practice of in-

dicating the superelevation at each curve by means of posts or signs which are set usually at the sod line or edge of roadbed, 9 1/2 to 12 feet from center of track and opposite the points of curve, spiral and tangent (see fig. 1). At curves without spirals, the posts may be set opposite the ends of the runout, on either side of the point of curve. The location of these posts, however, is not always as exact as that of the curve monuments. Usually they are marked with the elevation : 0 at the PC or at beginning of runout and the full figure at PS, or at end of runout. In some cases, the first or zero post is marked also with the runout inclination (1 inch in 60 or 67 feet) and the second post shows the full elevation and the degree of curve.

Two types of curve elevation posts are shown in figure 2. In the design at the left only the elevation is marked. In the design at the right the end posts have zero elevation on one side and « T » (tangent) on the other side; the inner posts show the full elevation and also the degree of curve (down to 1/4 degree). In this design the figures are in relief on malleable iron plates bolted to a creosoted post.

Diversity of opinion and practice in the widening of gage on curves, in order to facilitate the passage of locomotives, is as wide as the diversity in elevating rails on curves. Thus on twenty-two railroads standard gage is maintained up to curvatures ranging from 3 degrees as a minimum to 18 degrees as a maximum. In more detail, 3 degrees is the limit on one road, 4 degrees on two, 5 degrees on eight, 6 degrees on one, 8 degrees on six, and 9, 10, 12 and 18 degrees on one railroad each. Four roads report that gage is not widened at all on main track curves, two of them stating that their curvature does not require it. Of the other two, both operating long lines over prairie and mountainous country, one makes an exception for curves of 10 to 12 degrees through yards and the other states that locomotive tires are set to a gage which will allow for curvature.

Difference in wheelbase and wheel gage of large locomotives is theoretically a factor, but so many railroads now operate engines of long wheelbase that this factor can have little weight in accounting for the diversity of practice noted above. The Americain Railway Engineering Association recommends standard gage up to and including 8 degree curves, and then widening 1/8 inch for each 2 degrees up to a maximum of 4 ft. 9 1/4 in.

Increments in widening are generally 1/8 inch for each two degrees (or fraction thereof) or 1/4 inch for each 4 degrees. On one road the rule is carried to a refinement of 1/16 inch for each degree, beginning with 4 ft. 8 9/16 in. for 6 degree curves. In this case, as in cases where rules require superelevation to be varied by increments of 1/8 inch, it may be doubted whether such close graduation is maintained in practice. For maximum gage permissible, including wear of rail heads, four limits are given by different roads as follows : 4 ft. 9 in., 4 ft. 9 1/8 in., 4 ft. 9 1/4 in. and 4 ft. 9 1/2 in. Rules sometimes specify the use of special track gages for curves to insure accuracy of widened gage.

The diversity of practice in regard to gage is emphasized by the contrasting statements in railway companies' books of maintenance rules quoted below, although in some cases these statements refer particularly to tangents. It is further noted in some of these books that kinks in gage are as detrimental as low joints in surface and must be corrected. In regard to the second quotation, other roads have rules which approximate the first sentence, but with the term « proper » or « uniform » instead of « perfect », thus giving a very different sense to the paragraph :

a) « Slight variations from gage are not objectionable, provided that they are

uniform and continuous over long distances;

b) « Perfect gage is one of the principal features in good track. Gage must be exact and uniform as prescribed. »

It is sometimes pointed out in the rules that rectification of gage need not be attempted as long as the width is regular or uniform and does not exceed certain limits. This caution provides against unnecessary labor and work and undue damage to ties and track material by the shifting and respiking of rails.

Turnouts on the inside of curves are objectionable, since standard gage is required through turnouts, so that the normal widening of gage must be interrupted. Some roads require speed reduction on such curves. With turnouts on the outside of widened curves, the standard flangeway width at main line guard rail is increased by an amount equal to the widening of gage.

Increase in gage is obtained usually by shifting the inner rail outward and is maintained for the full length of the main on circular curve. The transition from standard to widened gage is made in conformity with the spiral, or on the tangent if the curve is not spiralled.

A request for suggestions as to means of improving the stability or permanence of track on main-line curves produced but meager results. In general, the replies covered good maintenance and heavy track construction. The first includes correct alignment, with transition curves, uniform gage and uniform superelevation. One suggestion is to facilitate maintenance by placing 40-inch iron pins at all curve points, the center line being marked on the head with a cold chisel.

Suggestions for track construction include heavy rails, ample supply of good ties, well-drained roadbed, a heavy bed of crushed stone or gravel ballast kept well tamped, heavy tie plates, double spiking and the use of sufficient rail anchors or other means to prevent creeping. In view of the lateral pressures, some engineers suggest shoulder tie-plates, large ties and a heavy shoulder of ballast. Canting or inclining the rails inward from the vertical, so as to be perpendicular to the pressure, is advocated by two roads, one of which points out that this inclination should be given by special tie plates and not by adzing the ties. A corollary to this is the statement that in no case should the rails be allowed to turn out or incline outward from the vertical due to wheel pressure or tie wear.

Reduction of superelevation is the most radical suggestion, one engineer making this definitely and another indirectly by pointing out that if superelevation is increased to suit the speed, the speed is likely to be further increased. In the first reply, it is remarked that such reduction probably will give greater relief than any other measure. It is considered specially desirable for tracks used by both fast passenger trains and slow heavy freight trains. On certain portions of this road, trouble from derailment has been practically eliminated by reducing the superelevation of 3 degree curves from 5 inches to a maximum of 3 inches. As it is expensive to carry out such a change over a considerable mileage it may be introduced in connection with other work, or when the track is being ballasted or surfaced.

To equalize train resistance it is usual to compensate or reduce grades for curvature, in order that the combined grade and curve resistance will not exceed the grade resistance on tangent. The present information given as to present practice in this respect supplements earlier information in *Engineering News* of 16 April 1908, p. 419, and 15 August 1912, pp. 278 and 308. The rate of compensation should properly take into account the local physical and operating conditions.

Uniform compensation or reduction of

grade at the rate of 0.04 % per degree of curve, regardless of variations of curvature and speed, is by far the most general rule, although some railroads specify or allow modifications to meet special conditions, especially in the use of increased compensation where steep grades reduce the speed or where stations may necessitate the stopping of trains. On one large system there is no prescribed rule but the matter is left to the judgment of the local engineers.

The minimum compensation noted is 0.03%, used by two roads. The maximum is 0.05, used by three roads, though only one of these makes it a uniform standard. One engineer reports that dynamometer tests have shown 0.04 to be insufficient for sharp curves, and recommends going as high as 0.06 %. Out of twenty-four roads, sixteen use 0.04, mainly as a uniform rule. Two use 0.03; four use 0.035, one uses 0.045 and one uses 0.05.

Some of the modifications or qualifications for compensating grade on curves according to local conditions are noted below :

1° On maximum grades with a large amount of curvature, 0.04 % compensation is used up to 10 degree curves, but this is increased to 0.05 on grades with few curves. Grade at sidings must not exceed 0.4 %. A decrease of 0.1 % in grade must be allowed for vertical curves;

2° Compensation is 0.04 %, the uphill end being equated and carried out on the tangent;

3° A good rule is 0.035, as 0.03 is scarcely sufficient and 0.04 makes the pull on the drawbar a little less on heavy curves than on tangents;

4° Although our rule is for a standard compensation of 0.04, a correct and scientific rule would recognize in some way the degree of curve as being a function of curve resistance. Thus if 0.04 is proper for a curve of 12 degrees it does not follow that it is proper for one of 2 degrees;

5° Although the American Railway Engineering Association suggests 0.03 compensation up to 2 degree curves, we use 0.04 for all degrees and have found it satisfactory;

6° Ordinarily, 0.035 is used, but this is increased to 0.04 on steep grades with sharp curves;

7° Ordinarily 0.04, but 0.05 at stations or points where trains are likely to stop;

8° Compensation is 0.03 on the open line and 0.05 at points where speed is restricted or trains stop;

9° Compensation is uniformly 0.04, for although present conditions may call for reduced speed at certain points we cannot tell when conditions of increased power or decreased tonnage may make it desirable to maintain regular speed. There should be a greater rate of compensation where the track is used by both freight and passenger trains, since there is more friction and resistance where the superelevation is adjusted for normal and safe passenger movements but also carries full-tonnage freight movements.

As to the basis of these rules, most of the reports state that it is general practice and experience and all of them state that no recent tests have been made. Two refer to tests made about twenty years ago, three accept the recommendations of the American Railway Engineering Association and one bases its practice upon the Wellington investigation of 1878.

Conclusion.

From the information presented in this article it is apparent that considerable diversity of opinion and practice exists in regard to curve work. Since proper condition of curves is so essential to efficient operation and economical maintenance, it is rather surprising that the permanent marking and monumenting of curves is not more general. Such work is inexpensive and in many cases a policy of checking the curves and then marking

them would be well worth while. As to means of increasing the stability of track on curves and thus reducing maintenance work and expense, suggestions are mainly for heavier construction, although an important suggestion is for a general reduction in the amount of superelevation of rails.

It is evident that present formulas for superelevation of rails on curves give results which are barely applicable under modern conditions. In fact, these results would be misleading if they were not modified materially in the light of actual experience. It is evident also that modern heavy locomotives with long rigid wheelbase constitute a factor that must be reckoned with in curve layout and maintenance. Variation in gage of driving wheels on different axles in order to facilitate the passage of curves is common practice, but there is little uniformity and the arrangement appears to be mainly arbitrary. Under such conditions the engineer is at a disadvantage in deciding what amount of widening of the track gage should be introduced on curves.

Curve elevation and grade compensation for curvature both involve scientific investigation as a basis, although practical considerations must modify the application of results thus obtained. It appears, however, that no extended modern investigations or tests have been made to determine the accuracy of existing methods or the extent to which mathematical analysis needs to be modified to meet modern conditions. Reliance is placed largely on tests and investigations made many years ago, when size of engine and weight of train were very different from conditions involved in present railway operation. On the other hand, even greater reliance is placed upon actual experience and observation, since theoretical methods now in use do not meet practical conditions. For these reasons, a broad and thorough investigation of train resistance under modern conditions with modern equipment appears desirable.

It has been pointed out that curve superelevation and alignment, with other items of track maintenance work, were neglected during the war and under government operation of the railways. Since the war, labor and other conditions have not been favorable to prompt restoration of normal standards of maintenance. Consequently, there is a wide field for revision and improvement and perhaps an opportunity for important innovations.

[656 .253]

Location of signals as an aid to traffic working, (1)

By R. S. PROUD,

ASSISTANT TO THE SIGNAL ENGINEER OF THE METROPOLITAN DISTRICT & LONDON ELECTRIC RAILWAYS.

Figs. 1 to 4, pp. 1231 to 1237.

(The Railway Engineer.)

The object of this paper is to bring to notice some of the methods used when deciding upon the best location for signals, especially where automatic signals are to be provided.

The method advocated is first to study

(1) Abstract of paper read before the Institution of Railway Signal Engineers, 20 April 1922.

the lay-out of the signals in terms of time rather than distance, *viz.*, to arrange the sections in such a way that a train will take about the same time to travel through each section. After the theoretical positions have been decided upon, the proposed sites will have to be viewed to ascertain whether they are practicable ones. If they are not suitable, due to bad sighting, difficulty of fixing, or other cause, the work already done will not be lost, as it will give information as to next best position.

A graphical method is usually adopted for ascertaining the best locations, graph being plotted for the train travelling through the line, the ordinates being used for time and the abscissæ as distance, or *vice versa.*

Before drawing the graph it is best to obtain as much information as possible on the following points:

1° The number of trains on each line that it is proposed to run, or are likely to be run in the future; and the shortest time interval between trains;

2° Average speed of the trains running over the portion of line, with the maximum and minimum speeds likely to be run; also some idea as to the number of trains of the various speeds;

3° Acceleration and deceleration of all classes of trains;

4° Type of traffic dealt with; and any special class of trains or traffic-working;

5° Length of average station stop in time;

6° Physical characteristics of the line, such as gradients, curves, cuttings, banks, viaducts, tunnels, lay-outs of junction and yards, single lines, bottle-necks, etc.;

7° Places where special speed restrictions are to be observed.

Having decided upon the headway: 1° the next step is to consider the information required in item; 2° if there is a great difference in speed, it would be best to consider the average speed of the slower passenger trains. Particulars of the high speeds will also be required to calculate the overlaps. These speeds will have to be obtained by means of observations on the ground, or by recording instruments on the trains; and where the physical characteristics of the line vary, observations should be taken at various points to ascertain how they affect the speeds.

Each time section consists virtually of four parts, *viz.:*

1° Sighting allowance for signal;
2° Distance between signals;
3° Overlap;
4° Length of train.

The time distance curve can now be plotted, and this will show graphically the position of the train as it travels through the section of line; and takes into consideration variation of speed due to gradients, curves, permanent speed restrictions, etc, This graph should be compiled as carefully and accurately as possible.

Figure 1 shows such a graph which is compiled by starting from some fixed point and plotting to suitable scales, a curve representing the distance travelled by the train from zero, after different intervals of time; if the curve indicates the position of the front of the train, a similar curve, separated from the first by a distance equal to the scale length of train, will represent the rear of train. The graphs in question are for a train travelling up a steep grade at 20 miles per hour, and after about half a mile, reaching the top and accelerating up to 35 miles per hour, then braking to a stop in the station; and after 50 seconds, starting up again, reaching 30 miles per hour. Particulars of acceleration, etc., are given on diagram. Signalling to be provided for a three-minute service, but as it is assumed that the service may want to be increased somewhat in the course of a few years, provision should be made for a headway of say 160 seconds.

We are now in a position to lay out the signal sections, and the first consideration will be the points at which signals will have to be fixed regardless of track capacity, such as junctions, stations. etc. Whilst it is not absolutely essential that signals should be provided at stations if there are no points, it is preferable to install at least starting signals, and in most cases home signals.

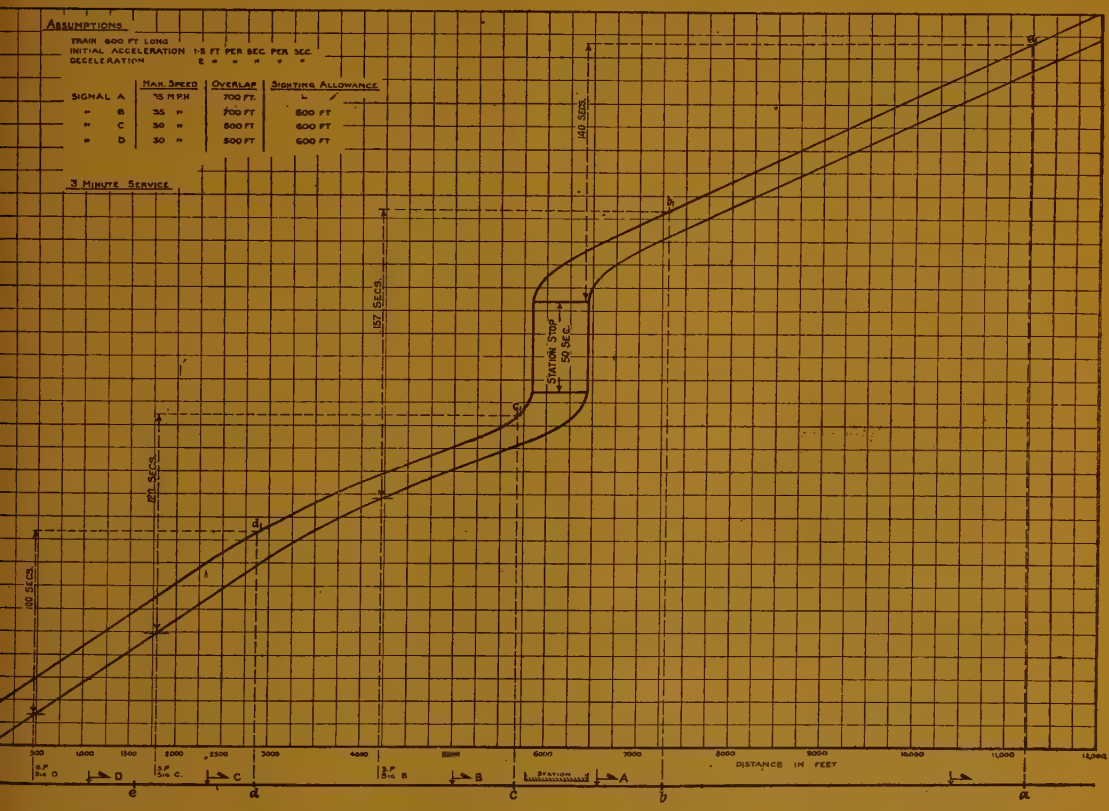


Fig. 1 — Graph showing distance travelled by a train from zero, at different intervals of time.

Starting signal sections. — Where no junction occurs, the section controlling the starting signal should be somewhat longer in terms of time than the intermediate sections, but still keeping it less than the actual headway required. This will ensure, as far as possible in normal working, that once a train has started from a station it will not be checked by signal. This section would thus tend to respace automatically the trains at regular intervals if they had become somewhat bunched up; also, if a check or stoppage took place it would be most likely to occur at a station, which is preferable, especially during the night, or in foggy weather, when there is the possibility of passengers mistaking the stopping place and attempting to alight. If the station platform is the full length of the longest train, the best position for the starting signal will be about 100 feet

beyond the platform, except in the case of a very frequent train service, when this distance should be decreased. If the platform is short, the best position will be at a point measured from the rear end of the platform equal to the length of the longest train to be accommodated, plus about 100 feet. This will allow a train which is too long for the platform to draw ahead and bring the rear coaches into the platform without passing the starter.

The starting signal position can, therefore, be plotted on the graph. The length of section, as explained previously, should be longer than for an intermediate signal, in this case about 140 seconds. To obtain the position for clearing point of signal A, draw a line vertically from the point where front of train is starting up, and measure off 140 seconds, project a line from this point horizontally to the right and where it cuts the rear graph at point a_1, project a line downwards, and this will be position of clearing point of signal A. The overlap on the starting signal can be plotted in, and should be sufficient for the highest speed of trains which do not stop at the stations. This position *b* will be the clearing point of home signal B.

Home signal location. — As the section controlling the home signal will include the time spent by the train stopping at the station, shown in figure 1 as 50 seconds, it is best to make this section as short as possible in terms of distance, unless the station stop is short, and the time between trains is long. This can be done by putting the clearing point *c* of the intermediate signal C close to the platform, say 100 feet or less, in the rear of same; the position of home signal B would then be overlap distance from that point.

From signal B measure off a distance in rear of same equal to the sighting allowance, and from that point draw a vertical cutting « the front of train » graph, then the vertical distance from there to an horizontal line drawn through point *b*, will represent the length of the home section in time, in this case 157 seconds; and as a three-minute service is to be catered for, it is evident that the station stop must not be longer than 73 seconds.

Where lines are to be signalled for a fairly frequent service, it will be found that the home section will generally be the limiting section for the line. This is particularly so in the case of rapid transit lines. Short platforms tend to aggravate this trouble, due to a long train having to draw up twice to bring all the coaches opposite the platform, thus adding to the length of the station stop.

Intermediate signals.— It is sometimes usual to fix an intermediate signal for one road opposite a signal for the other road; and while, no doubt, this is often an economical arrangement so far as construction is concerned, it should not be done unless it coincides within a short distance of the best position from a traffic point of view.

Local conditions must be kept in mind all the time the signalling is being laid out; for instance, in the case of a long up-grade, it would be more economical to make these sections shorter in terms of time than those on the level, in order to minimise as much as possible the chance of a train being stopped on a gradient, with consequent loss of time and energy, due to the difficulty in restarting a heavy train. A train berth sufficient to accommodate the longest train should be provided in the rear of all signals.

Referring again to figure 1, it is now possible to plot the position of signal C. From clearing point *c* draw an horizontal line, from this measure downwards a distance representing the time required for the section (in this case 120 seconds), from this point draw an horizontal line until it cuts front of train graph, project

down to the abscissæ, and this represents the sighting point for signal C; from this point measure a distance towards B equal to the sighting allowance required, this will determine situation of signal C; in the same direction measure another distance equal to the overlap required, this will constitute the clearing point of signal D. In the same way signal D position can be plotted, but in this case the time of section should be decreased to say 100 seconds, owing to the presence of a steep up-grade, and the inadvisibility of stopping a train on an up-grade, as mentioned previously.

The above signals have been laid out working backwards owing to the position of starting signal being fixed, but if desired the position can be calculated in a forward direction whichever is considered the more suitable.

Special consideration needs to be given to the lay-out of the signalling in the following cases:

a) Where a line with several routes converges into one, and after some distance diverges into two or more branches, thus forming a bottle-neck; such a bottle-neck should be signalled for a much greater service of trains than the other routes, in order to allow the branches to be used to their required capacity;

b) Junctions;

c) Busy stations.

Sighting allowance for signals. — This question is a very important one. The distance away from the signal at which a driver should receive a « Clear » indication is dependent upon the maximum speed and weight of trains, braking efficiency of train, gradient, etc. — in fact, the same factors as required to calculate the overlap, which is a function of the braking distance. If, therefore, we know the braking distance for the maximum speed, and add an ample percentage to cover the time taken by the driver to act on the indication, and for other contingencies, this would appear to be the best distance to allow. Where a sufficient sight cannot be obtained of a stop signal, a repeating signal should be provided; this signal acting as a distant and being simply an indication of the position of the signal it repeats.

Wherever possible repeater signals should be fixed so that, as soon as a driver has passed the repeater, he will be able to sight the stop signal, thus having a continuous indication of the signal aspect; if there is a gap between passing the repeater and sighting the stop signal, the aspect of the latter may have changed, either having « cleared, » in which case time has been lost by slow running; or if for any reason the signal has been returned to « Danger », the driver may have difficulty in avoiding overrunning it. It might be an advantage in some cases to install an additional repeater.

The above remarks apply to the distance away at which a driver should receive a « Clear » indication, and not to the distance away that a signal should be actually visible; and while it is essential that a driver should see a signal in plenty of time to act, too long sight of same may lead to unnecessarily slow running, due to a driver slowing up, for instance, when he sees a signal at « Danger »; whereas, perhaps, he could run some considerable distance at normal speed and still have ample margin for stopping; in the meantime probably the signal has « cleared, » and unnecessary loss of time is thereby made.

In certain cases it may be justifiable deliberately to give a shorter sighting distance than could be obtained. This would not apply where high speeds prevail, or where goods trains without continuous brakes travel over the line.

Fog repeater signals. — Where light signals are used during fog or snow instead of detonators, to indicate the aspect of the signal in advance, the best position of same would probably be in all cases at a definite fixed distance from

the signal it repeats; as these are more in the nature of « marker » lights, and would thus tend to give a driver an indication of how far he was from the signals. This distance might, perhaps, be modified somewhat for a very steep gradient.

In the case of automatic signals provided with overlaps, the fog repeater should be fixed in relation to the position of stop signal.

Where no overlaps are provided, it should be fixed at or a certain distance from the distant or repeater signal.

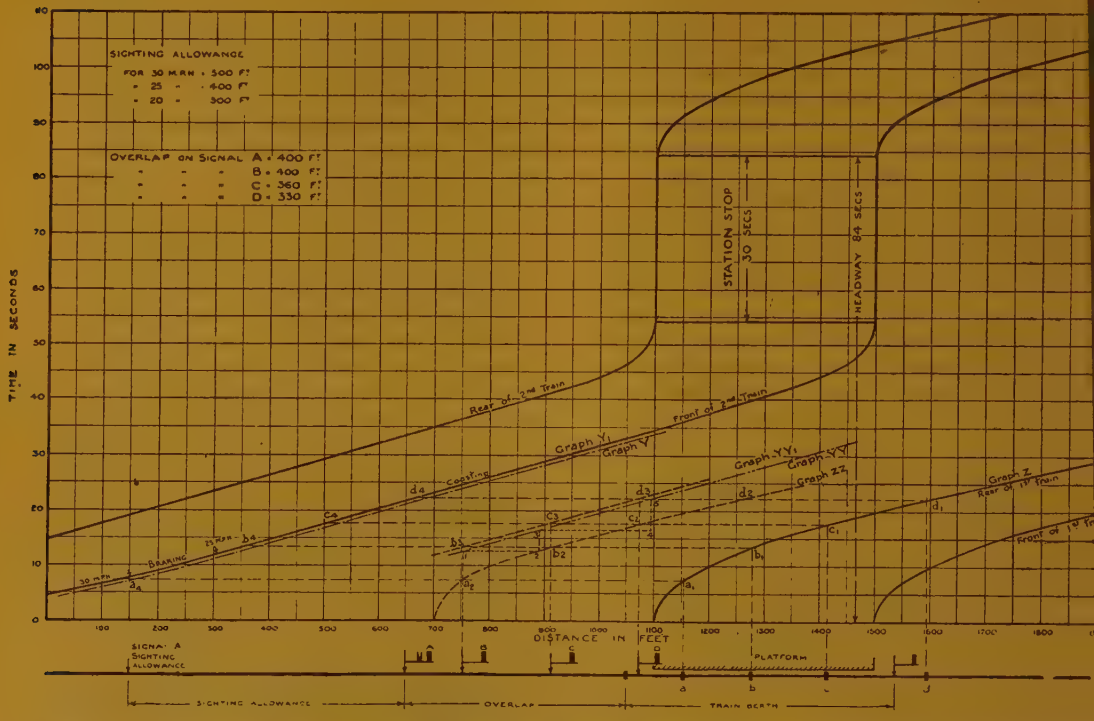


Fig. 2. — Form of graph used in the study of the best lay-out of signals, etc., and illustrating method of finding best position of signals and clearing points.

Suburban and rapid transit lines. — On lines where the principal traffic is a passenger one, with heavy peak loads during the morning and evening rush hours, the need for studying the signalling lay-out becomes acute. The signalling through stations in most cases will become the principal problem. Some of the factors, however, are altered; for instance, the speed and class of train to be catered for will probably be fairly uniform, and the acceleration and deceleration nearly constant. On the Underground Railways this question of the signalling through stations has received very great attention, and an attempt made to nullify the effect of the station stop as much as possible by the installation of extra home signals, which clear as the preceding train leaves the station. As many as four home signals have been provided at one station.

The position of these signals affects very considerably the results obtained,

and figure 2 shows the form of graph used in the study of the best lay-out.

The position of the starting signal should be fixed first, in this case about 50 feet beyond the platform, provided platforms are about the same length as the trains; this allows the clearing point of signal D to be settled, *viz.*, overlap distance beyond the starter. On the underground railways the overlaps are based on the average braking efficiency of the trains, allowance being made for the gradient beyond the signal, and to this distance is added another 30 % to cover contingencies; but in the case of starting signals at stations where all trains stop, an overlap is provided sufficient for about 10 miles per hour.

The length of train berth is the next item to settle. This will extend from the starting signal to the end of overlap on signal A, and should be about 50 feet to 100 feet more than the maximum length of train. If the train berth is only just sufficient to accommodate a train, it will mean that all drivers must pull up at one definite spot; and unless a certain latitude is allowed, they will be afraid of overrunning the mark, and therefore come into platform slower than is necessary, thus losing very valuable time. Having decided on the length of berth, measure the distance in rear of the starter, and it will give the end of overlap on the outer home signal A; measure back the overlap distance, and this fixes the position of signal A. A repeating signal should be fixed under same which would only show « Clear » when all home signals are clear. The time distance curve Z for a train leaving the station should now be plotted, starting from a point about 1 100 feet from zero. With one home signal, the time from the starting up of train to the home signal clearing will be the time taken by rear of train to clear point *d*. In order to allow a following train to arrive into station quicker, this time must be decreased, and more home signals installed.

Assuming the installation of four home signals. — The first clearing point to be decided upon will be for signal A, and this should be fixed just under the longest train distance from starting signal, so that if a train pulls right up to starter, it will hold the home signal at « Danger, » but will clear same very quickly after starting up. Signal B will be fixed overlap distance from this point. With shorter trains pulling well up to starter, they would clear point *a*, and therefore signal B would become the normal home signal.

Draw a vertical line from *a* cutting the graph Z at a_1, and an horizontal line through that point. If the sighting point of signal A is projected on to this line, we now have a position from which we can plot in a trail graph Y to represent the front end of the following train, assuming this train is approaching at 30 miles per hour with a sighting allowance of 500 feet, that is to say the front of train should be 500 feet away from signal A when it clears. As the driver would see the repeating signal at « Caution, » it is assumed that he would decelerate slightly, say down to 25 miles per hour, and then coast into station, provided signals cleared. The final position of this graph cannot be decided yet, but can be put in temporarily. The remaining signals and clearing points have now to be arranged so that a sufficient overlap and sighting allowance is given on all signals. The overlaps of the inner home signals are reduced somewhat, as it is most unlikely that drivers would run in at full speed unless the repeating signal is « clear. » As the speed of train decreases the sighting allowance can also be decreased.

In many cases the theoretically best position for signal D would be inside the station; but in practice it is questionable whether this would be a good arrangement, because in the unlikely event of a train being stopped at such a signal, part of the train would be in the station and part outside. It is assumed,

therefore, that this signal would never be fixed more than a very short distance inside the station.

A method for finding the best position for signals and clearing points is to draw another graph ZZ parallel to Z, but at a distance equal to the overlap to be allowed at the various points; this would give the shortest distance permissible between trains. Sighting must also be allowed for, and a graph YY should be drawn sighting allowance distance from Y. It is now required to arrange the signals in such a way that the time taken by the first train to travel from one clearing point to the next is the same as the time occupied by the following train in travelling from one sighting point to the next. This can be done by trial and error, or by further graphical construction, as shown in figure 2. From the point a_2 draw a vertical cutting YY at 1, from 1 draw an horizontal line cutting ZZ at 2, draw another vertical from 2 cutting YY at 3, from 3 draw an horizontal. From d project a vertical line cutting Z at d_1, from there draw an horizontal cutting YY at 5, from that point draw a vertical line cutting horizontal line drawn through 3 at a point 4. The time represented by the three verticals between graphs ZZ and YY should be equal to the time taken by train to travel from a to d. If, therefore, the time represented by the vertical distance between graph ZZ and point 4 is divided up equally among the three verticals, we shall obtain points through which another graph YY_1 similar to YY can be drawn; if now the same process is repeated, it will be found that all verticals keep inside the two graphs. If the two graphs YY and ZZ had been too far apart, a similar method could have been adopted, and by subtracting from, instead of adding to the verticals, would have given the position of YY_1. Measuring back sighting allowance distance from YY_1 will give the correct position for the following train graph.

If the vertical lines c_3, b_2 and d_3, c_2 are extended, they will give the position of signals C and D respectively. Extend the horizontal lines b_3, b_2, c_3, c_2 and d_3, d_2 cutting Z at b_1, c_1 and d_1, then vertical lines from these points will give the position of clearing points b, c, and d respectively.

The points b_4, c_4, d_4 indicate respectively the position of the front of the second train when signals B, C and D are clear.

Graph Y_1 represents the following train approaching station and coming to rest; the continuation of this line vertically represents the time expended in the station, and the time from starting up of first train to starting up of following train is the headway permissible with that length of station stop.

To save confusion, only the necessary portions of the graphs have been drawn in.

The acceleration and deceleration of trains has a great influence on the headway that can be obtained. Poor braking means that longer overlaps must be provided, and longer sighting will be required. This question becomes very important where a frequent service is essential. Figure 3 gives approximate headways possible with various acceleration and decelerations, which have been taken as being the same for the sake of simplicity.

Choice of systems. — There are many systems of automatic signalling, which may be broadly divided as follows :

A) Ordinary two-position signalling, with one stop signal per block section;

B) Two-position signalling, with overlap extending from one signal to next. Two signals per block section;

C) Three-position signalling.

The three systems are shown in figure 4, and careful consideration should be given as to the best system for adoption on any particular line.

C is the more modern, and is most

suited for main lines, where there is a large variation in type and speeds of trains, and not very frequent service; in which case the signals become practically speed signals, slow passenger trains running to the 45° position, and goods trains and fast passenger trains running to the 90° position. It is probably an improvement on and less expensive than B, but is more expensive than A; and it is questionable whether it is suitable for moderately low speed, close headway traffic, due to the likelihood of the signals being more often in the 45°

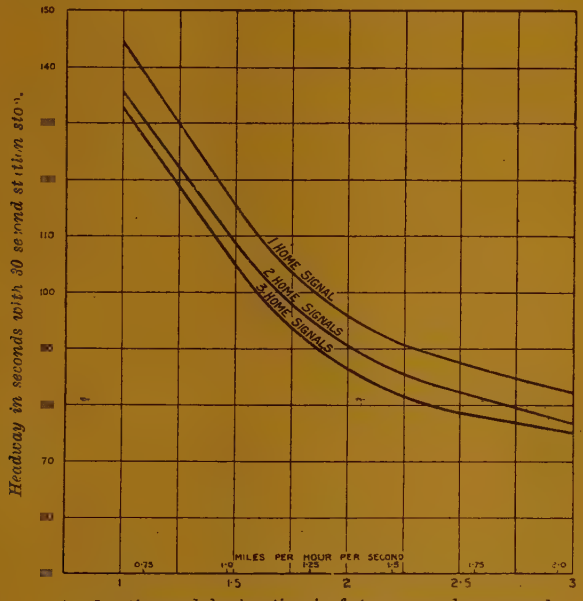


Fig. 3. — Approximate headways possible with various accelerations or decelerations.

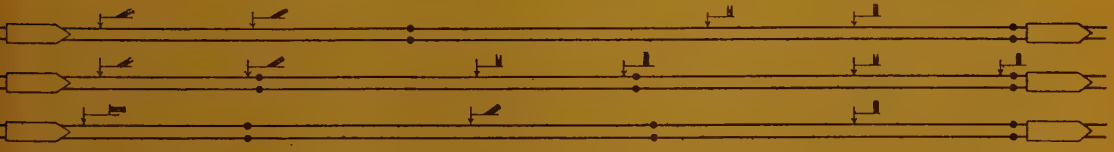


Fig. 4. — Diagram showing the location of signals, etc., in the three principal systems of automatic signalling.

than the 90° position, unless the signals are very close, in which case the berth at signal may not be sufficient for the length of train.

While three-position signalling is in great favour at present, and has many decided advantages, there is ground for a great deal more discussion on the subject of the various systems. Each system will have its influence on the best location of the signals, but the method as set out in this paper will, the author believes, help in finding these positions, whatever the system.

[385 .1 (42)]

The Railway Act 1921, (1)

By the Rt. Hon. Sir Eric C. GEDDES, G. C. B., G. B. E.

(*The Engineer.*)

The post-war legislative effort in connection with railways culminated in the Act of 1921. By that Act, we — that is to say, those of us who were responsible both for the framing and passage of the measure, and for the very useful and co-operative consultations which took place during that period — believed, so far as we could see, that we had provided for the reconstitution of our railway system on a modern basis, and for facilities which eminent engineers of every class had desired. We believed that many economies would result, and that we had secured a reasonable hope of the financial stability of our railway system.

It is my purpose to offer a few observations as to the directions in which the benefits will accrue to the three great parties concerned in our railway system, namely, the general public, labour, and the proprietors.

I must necessarily be brief over portions of the reconstituted railway position. The Act provided a machinery, agreed voluntarily and between the associated railway companies and the great railway trade unions, for the prevention of disastrous disputes which from time to time have been so serious to the railway companies and the men themselves, and so detrimental to the industries and general public which they serve. This was not the Government conception, but was the uninfluenced proposition of employers and employed.

The Act also provided for a revision of the obsolete classification of merchandise traffic by a separate expert, economical and business-like tribunal, and for the adjustment of classification as circumstances altered from time to time. It provided also that the old and vicious rigidity of the rate-fixing machine should be simplified on lines approved by both railways and the great trading interests.

There were those — as there always are when any great change is made — who were pessimistic, and notoriously so a certain very limited number of those who speak in the railway interests; but if we look at the position held by railway stocks to-day and compare it with the position when the Act was passed, I venture to think that even to-day this vital factor in our national life is on a basis which excites the envy of our other great industries which have not been similarly satisfactorily situated. It may indeed be said that railways have benefited unduly, but that I would not be prepared to admit. At the time the Act was passed railways were in a state of complete uncertainty. Their expenses had increased enormously — just over threefold; and if one casts one's mind back to the alarming reports which were circulated at the time — and which I personally did my best to contradict — one cannot but wonder that the investing public showed even the confidence, and the railway shareholder the steadiness which they did. At the same time, with the return to legislative stability, and with the cessation of that most pernicious of all things — a guarantee to the management by the Government —

(1) The Junior Institution of Engineers. The Gustave Canet Lecture, delivered on Thursday, 1 June 1922. Abridged.

railway undertakings have risen in public favour.

One may be asked, « But where does the trader come in? » And in reply to that I would say that already reductions in charges are being felt; not a return to pre-war charges, of course, and not as much reduction as will eventually come about, because you cannot expect to overcome the disadvantages of years of war, the abnormal costs ruling, and the evils of Government guarantee in a few months. But I feel confident that, as the railways feel their power, as they realise the possibilities which are open to them under the provisions of the Act of 1921, and as the traders come to recognise that they must help the railways if they wish to get freights down — by reducing detentions to rolling stock, by better loading of wagons, and by co-operation generally — goods and passenger costs, which bear so heavily on the community to-day, will be reduced.

The Railway Act of 1921 is really a « traders' charter », and with the great trading organisations which exist, they can afford, and well afford, the best brains and the greatest skill to enable them to take advantage of that charter. The companies can now induce the co-operation of the trader by offering lower rates whenever the trader will help them to work more cheaply.

As to the third party — the employees — they made a bargain for the reduction of their wages as costs of living fell, and they have honourably stood by that bargain. I wonder if the general public, or even the specialist public which I am addressing, realises that there has been a reduction — without dislocation or dispute, strike or stoppage, an almost automatic reduction — of £25 000 000 a year on the wages bill of the railway companies. But even so, the rates paid to labour are a vast improvement on the pre-war rates. I do not think that, under existing conditions, there is any prudent man who would wish the railway worker as a whole to return to his pre-war rates, and the machinery of the Act provides for a reasonable and cool consideration of these matters. Amalgamation will help to maintain a reasonable standard of remuneration to their staff.

Economic questions.

It is on economics — and more particularly on enonomics of a practical kind, which would interest engineers — that I invite you to direct your attention. Now, the one great feature of the Act of 1921 was that it amalgamated roughly one hundred and twenty companies of greater or less importance into four great groups. There was the Eastern Group, the Southern Group, the Western Group, and the Nord-West Midland Group. That was not done merely to make a picture on a map. It was done because a concensus of the best opinion available was that economy could only be obtained by amalgamation. Certain railways had in the past twenty years attempted great amalgamations, almost comparable to what was done by this Act, but for one reason or another they never got complete amalgamation. They never got complete fusion; they only got an elimination of competition and a pooling of receipts, but not an amalgamation of resources or a fusion of capital. They did that without any modern parliamentary sanction, and the trading community received no special protection.

It is a peculiar thing, but the mere fact of eliminating competition by these pools, in so far as the public were concerned, gave rise to a new competition as between the railways with which the public was not so intimately concerned at the moment, and that competition was to keep down even judicious expenditure. Let me make myself clear. Each partner in the pool has a certain fraction given it of the receipts of the pool, whether it earned it or not. Therefore no company got 100 % of the benefit which accrued from capital expenditure for development purposes. Any new business that it set itself out to

get by development was shared by the others, whether or not they did anything themselves; and in my judgment — and in the judgment of those who evolved with me the Railway Act of 1921 — that was one of the most pernicious and fatal principles which could possibly have crept into our great transport system. By the Act of 1921 railways were awarded the right to complete fusion, and they were denied the right of uncontrolled pooling without fusion of resources. It was believed, and is still believed, that with that fusion economies can be made.

The economies fall into certain well-defined classes. In the first place, there are the ordinary administrative economies which should result from amalgamation; and prominent in the public eye, but minor in importance comparatively, an example of this is the fusion of the railway boards. There were at the time of the passing of the Act some 1 300 directors of British railways, and after the passing of the Act there will be about 100. But when you are talking of a revenue expenditure of over £225 000 000 a year, this is comparatively a small thing, as the total remuneration to the railway directors of the kingdom was under £200 000 a year.

Then there is the question of amalgamation of management and control, and of reduction in expenditure by administrative changes; and there direct and substantial economies can undoubtedly be made.

Then, again, economies can be made on the traffic side by the better utilisation of plant and equipment, of way and works, by the better loading of wagons, and by the better turn round of locomotives. Under this head of saving in traffic there is no doubt that large economies can be realised in both capital and revenue expenditure, after complete amalgamation, by the use of alternative lines in a group, where spare capacity existed under separate management and ownership, and by eliminating the heavy shunting at the exchange points, which will now be largely reduced owing to the fusions which have been sanctioned. Obviously, the greater facility for routing traffic over other lines must be of inestimable importance, and would not be without advantage to the trader, as it will shorten the transit time, and will in the end contribute towards the possibility of reduced charges. I make bold to say that in one group alone several millions will be saved by this freedom of routing traffic over other lines in the group which hitherto carried an inadequate load.

Better use of stock can be obtained, especially if the rolling stock is of particular and specialised design. The advantage of fluidity of reserves needs no elaboration from me, and is a point of great economic importance to our grouped railway systems and to the trader.

Ways and works.

Duplicate stations exist in many places which are really of little, if any, advantage to the public, but by the reduction of unnecessary passenger and goods stations and marshalling facilities great economies can be made. The saving in the cost of collection and delivery to our great railway companies — notably in London — has already been demonstrated in many instances; but this can be much further developed, as great savings can undoubtedly be effected by unified services.

Unified administration, including the fluidity of stores and reserves, hold out hopes of economies which the railway companies will be ready and quick to realise; but it is on the engineering side, coupled with the traffic side, that one looks for the greater economies to be realised. Electrification, prudently and carefully carried out, holds out great possibilities. Improvement in rolling stock, elimination of dual fitting, standardisation of locomotives, wagons and parts, machinery and plant, are all directions in which savings can be made; and it is there that the members of this Institution will be more particularly interested. In round figures, the expenditure on the mainte-

nance and renewal of way and works on the principal railways which will be affected by the grouping system amounted in 1913 to about £10 500 000. In 1921, it amounted to over £30 000 000. On docks, harbours and canals maintenance was £750 000 in 1913, and in 1921 over £2 000 000. So that we have something between £30 000 000 and £35 000 000 to consider under the heading of maintenance of way and works, and harbours, docks and canals. A pretty considerable figure!

Probable savings as a result of the grouping system are necessarily extremely difficult to estimate in money values, but the following are the main heads under which economies may be looked for : superintendence, by the reduction of large numbers of separate designing staffs and a concentration of these in the offices of four engineers.

Already our railway engineers have the standard section for British rails, but as opportunity offers standard designs for permanent way fastenings, fittings and girder bridges should result in savings; and a concentration of engineers' stores and reduction in stocks, brought about by the fluidity of reserves, will give a consequent saving in both storage and capital. And I make bold to say that, under the heading of maintenance, great possibilities for coordination and elimination of waste exist when you only have four great civil engineering departments in the country so far as railways are concerned.

What is true about civil engineering on railway way and works is similarly true about docks, harbours and canals, with the addition of a very wide field for standardisation in the moving machinery in a dock and by common and more effective use of dredging plant.

Closely allied to the savings on civil engineering is the question of signalling. This is always debatable ground — whether it should be civil or mechanical engineering; but in this branch of the engineering work of a railway we have undoubtedly a striking case where amalgamation should yield economies.

Then there is the question of loading gauge and axle load, so far only touched. This is a subject often discussed and sometimes considered, but now it awaits settlement by your profession on business lines, with fair hope of success.

Rolling stock.

Turning now to the mechanical side, in the handling of locomotive coal alone it appears that the amalgamation of railways will allow of great improvement. Railways use 13 500 000 tons of coal a year, but under their separate existence this coal was handled in retail all over the country. I venture to suggest that before many years under the sanctioned amalgamations one-third of this could be handled by the belt and coal tower method; and if we take a fair present day cost for this work as 9 d. per ton into and 9 d. out of stack by the present methods, the saving would be equivalent to £332 000 per annum. Even if a capital expenditure of £2 000 000 were incurred on the provision of improved handling appliances, a very handsome profit would remain. It must be clear that a group of railways, running to a common centre, could erect coaling appliances for the use of all comers, and the saving in handling would be very considerable, and in some cases haulage could be saved.

In the standardisation of locomotives, again, the prospects of economy and of better management are clear. There are, I believe, some hundreds of types of locomotives on British railways to-day, and the standardisation of locomotives to eight or ten types must necessarily be slow, as the number renewable by all companies is probably in the neighbourhood of 420 per annum out of 25 000 — an amazingly low rate. But if the four great groups, as soon as they are formed, can get together and agree that renewals shall be upon a standard basis of type suitable for their particular work — and agree-

ment among four is more probable than among one hundred — we may look, during the present generation, to a vast decrease in the cost of manufacture, in the cost of repairs and renewals, and last, but probably not least, to a saving of the vast amount of spare parts held for the hundreds of existing differing types.

What has been said about locomotives applies also to wagons, and this is one of the most important economies in question. If the standardisation of wagons and the improvement in the capacity, which most of the technical officers, both traffic and engineering, look for, can be realised, great savings will be in sight; but the wagons must be modern wagons, and a steady programme of standardisation and improvement must be embarked upon.

In the first place, as with locomotives and with existing stock, parts can be standardised as a temporary and provisional measure. Then wagons can be built to a standard design and gradually improved in capacity, and can be fitted with continuous brakes. It leaves me cold to say that it is no use increasing the capacity of a wagon because wagons are not loaded to their capacity to-day. Just as the trader must be called upon and coaxed and encouraged to give a good turn-round to the wagon, so must he be called upon and coaxed and encouraged to give a good load to the wagon, and he must be shown that it is to his financial advantage to load a wagon well. It is of small importance to get 10 s. a ton for 5 tons of goods in a 10-ton wagon, if by a little inducement to the trader you can get 10 tons of goods at 9 s. a ton into the same wagon. But 10 tons is, in my judgment, far too low a capacity to aim at. It may be that in this country, for the shorter distances, there is a class of traffic for which it would be useless to build the great wagons which are used across the Atlantic; but even in this country there is a class of traffic which justifies a large wagon. In order to get that wagon introduced into an old, congested country like this, the four great groups will have to lay down a programme. They have to get the goodwill of the dock authorities and of the traders; they have got to show them that it is to their advantage, both direct and indirect, to enable the railways to make the economies possible by the introduction of these wagons, and that it will redound to their partners in the efforts — namely, the dock companies and the works — if they will alter their equipment gradually and prudently in order to enable the larger wagon to be used.

I may be asked, «Why a larger wagon? » «Why a wagon with a continuous brake? » The answer to that is familiar to my audience. The larger wagon costs less to build, per ton of capacity, than the smaller wagon. The percentage of tare weight to gross weight is vastly less than in the smaller wagon. The larger wagon takes less length of track per ton of capacity than the smaller wagon, and the days of building railways across the prairie in this country are gone for ever; land is costly, and we must get better use out of our railway plant, whether it be track, marshalling yard, or running road.

But why continuous brakes? Because you cannot afford to have trains crawling along as they used to crawl. Now, with the lines congested, and with all the improvements in modern equipment for passenger traffic which are being installed, it is essential, if the fullest value is to be got out of our tracks, that wagons should be fitted with continuous brakes, but not dual fitted.

What has been said about railway companies' wagons so far applies to a greater extent to private wagons. An estimate has been made of the saving which would be effected in the shunting of privately owned wagons if they were railway owned, and this is put by very competent authorities at as formidable a figure as between £2 000 000 and £3 000 000 per annum in unnecessary shunting alone. If the traders' wagons of to-day were replaced by a similar capacity of 20-ton wagons a further saving in shunting alone would be £1 400 000.

Electrification.

The electrification of railways was growing up on exactly the same indiscriminate basis as had obtained in the wheel gauge, the loading gauge, and in the lack of standardisation of locomotive stock, plant, and equipment. After the war greater possibilities of standardisation seemed possible, and standard types of equipment were generally considered desirable. So long as the railways remain separate entities, however, there will always be the desire to break away from a standard, and I can only look to the possibilities of prudent adherence to standardisation after we have got complete amalgamation and fusion. It may be that under very exceptional circumstances one of the four great railways may decide to equip a particular line to different standards from those obtaining for the rest of its system, but I cannot conceive that being done except under the direct necessity and with great regret; and one must hope that, when there are only four great systems, the four chief electrical engineers will be able to agree upon common standards.

It is, however, not only in standardisation that economies by the application of electric power will be attained. As I see it, you electrify a line for one of two purposes : either to give a frequency of service on the multiple-unit system for the purpose of attracting traffic, or for an entirely different object, namely, to increase the capacity of the line and enable a greater volume of traffic to be carried with a minimum of capital and revenue expenditure. The first class of electrification must be justified on the possibilities of expansion of traffic. The second class is justified by economy and on the increase in the capacity of the line. (I am talking, of course, of the main justifications.) There are minor justifications, such as the absence of noise and smoke, etc.; and, of course, there are economies which can be obtained by the far better turn round of electric locomotive power and its more regular use and shorter time in shed or shop.

You may say, « But what does all this mean? What may be the result of all this saving and reorganisation? » That is a difficult question to answer. But I want to give a figure — a figure which has authority. A committee of six, composed of men who are as well qualified to advise as any in this country, advised me, when at the Ministry of Transport, that certain economies could be effected by measures of which I have ventured to give some indication. The best figure we could get — to put their recommendations into money — gave us something over £20 000 000 a year. But even that was not exhaustive, and, of course, includes nothing for fall in general costs and prices, and the ordinary economies which can be effected by close supervision and management. An entirely independent estimate was made in 1918 by the eminent accountant, Sir William Plender, and by Mr. F. Palmer, of Rendle, Palmer and Tritton, acting for the Government. They put the figure of possible economies on 1913 prices in the neighbourhood of £20 000 000. This was arrived at by an entirely different process, and without the economies which would result from the saving in administration due to the large amalgamations. These two figures give us a measure of the sort of sum which some experts think can be saved, and which would largely accrue to the trading community of the country when the railways have been able to give full effect to the enactement of last year. I do not believe that this can be done without amalgamations, and we must wait for these economies. Twenty million pounds saved would be a reduction of 8 1/2 % of the working expenses.

[656 .23 (.44)]

REVIEW OF TRAFFIC QUESTIONS

By G. ALLIX.

(*Revue politique et parlementaire.*)

Railway Rates and Commercial Working.

The question of railway rates is much in evidence at the present time. The existing rates on the French railways are not looked upon with satisfaction by the traders, judging by the storm of protests they have raised, not so much on account of the increase, as on account of the unequal burdens which the rates impose upon various industries.

It is common knowledge how these have been fixed. An increase of 25 % on all rates was authorised by the law of 31 March 1918. Subsequently, the increase, which had been decided upon long after it was due, being found to be quite insufficient to enable the railways to balance their receipts and expenses, it became necessary to take more drastic steps. The law of 14 February 1920 authorised further increases of 45 %, 50 % and 55 % on the passenger fares (3rd, 2nd and 1st classes) and of 115 % on the freight rates, these being percentages of the original rates and together with the first increase of 25 %, resulting in a total increase of 70, 75 and 80 % for passenger fares and 140 % for freight.

On the other hand, the time was considered opportune to introduce a reform which has long been considered necessary. The old system of rates was open to the objection of being complicated, confusing, encumbered with special rates and set forth in a folio of 1 700 pages which was needlessly enlarged by a large number of obsolete regulations and rates. It was hoped to be able to unify the rates, and this measure, after having been made the object of a resolution adopted by the Chamber on 2 February 1910, was advocated in 1910 and in 1912 by the deputies in charge of drawing up the financial statements in connection with the budget and interest garantees, but it had been found almost impossible to put into practice in normal times. Without mentioning the difficulty of upseting a host of private interests, at what level should the uniform rate be fixed? At the maximum rate? How could one justify or obtain the acceptance of such a rise? At the minimum rate? That would spell ruin to the railways.

The war has completely changed the situation; by affecting the value of the currency, it has made it necessary to raise the special and fixed rates, whilst the growing deficits of the railways made an increase in the rates necessary and allowed of their being unified. It has thus become possible, though not without serious difficulty, to substitute for the special rates, standard rates common to all the railways and at a fixed amount, based solely on a kilometric basis. The simplification is obvious, but it has resulted in an average increase of 30 % of the original base rates, not to mention much greater increases in the case of certain rates which formerly were particularly low. As the increases of 25 and 115 % (for goods) are applicable to

the unified rate, that is to say, have been already increased by 30 % on the average, it follows that transport which cost 100 units in 1914, costs subsequent to 1920, 312 units. The total increase over 1914 is thus, on the average 212 %, and for some forms of traffic, including some of the most important, it reaches a very high and almost prohibitive figure.

It is therefore necessary that the rates should be adjusted without delay in such a manner as to remedy the errors and undesirable features which can scarcely be avoided in the work of unification and which have become apparent in practice. It is necessary to amend the new scheme, though without reducing the total receipts of the railways. Considerable attention is being given to these points. Mr. Le Trocquer, the Minister of Public Works, has already provisionally approved a certain number of rates affecting the metal industry, which afford an appreciable relief compared with those previously in force. The unified and increased rates, drawn up in 1918 and 1920, not coming into force until 31 July 1922, it is necessary that in the six months which have still to run, the commission appointed by the Minister of Public Works to revise these in the best interests of all concerned, should complete its task. This commission has for its President one who is without doubt the highest authority on the question of rates and the commercial side of railway working, Mr. Richard Bloch, Engineer in Chief attached to the general management of the Orleans Company.

* * *

Mr. Bloch desires that everyone should have the opportunity of understanding the complicated questions which have arisen and on which such erroneous ideas are held by the general public. He has communicated the results of his many years of experience and investigation to a series of conferences, and these addresses collected and published in 1919 achieved the greatest success in the circles concerned. A new edition of his *Railway problems; an investigation of the commercial side* has just appeared (Librairie de l'Enseignement technique), having been brought up to date, and one cannot have a better guide.

Transport in general is a « service», the value of which may be determined by the law of supply and demand, and this is largely the ruling factor in the case of road, canal and sea transport. It is not so in the case of the railways, firstly because the great variation in circumstances (variety and quantity of products which have to be transported, of consignors, and of sending and receiving points) makes it practically impossible to determine the price in each particular case; secondly because a transport organisation which holds a monopoly ought to act with the strictest impartiality as regards their customers; and lastly, since the railway rates are at the root of the commerce of the country, it is necessary from a public point of view that these should be definitely fixed and approved by the Government. But how are these to be determined? According to the actual cost of transport? This would be simple, to the point of being absurd, for since the actual cost of transport is almost independent of the value of the goods, it would still be necessary to take this into account and therefore not charge for the lower priced articles at the same rate as for the higher. The result is the division of goods into classes (six at the present day), which are charged at different rates proportional to their average value. This classification it will be seen is entirely empirical.

Goods are not transported on account of their value, but on account of the profit which the consignor can realise by moving them from one place to another. The cost of transport must in

no case exceed the difference between the value of the goods at the sending and receiving points, because, if it absorbs the probable profit, the goods will not be sent. No amount of reduction of rates will cause the movement of a commodity from one place to another where it has the same value. No rates, however high, will prevent the transport on an indispensable commodity, but in practice the rates will be limited by competition with other producing centres, and by the law of the substitution of requirements which will cause a substitude to be used in place of a commodity which is excessively expensive. The problem is also complicated when several producing districts are in competition to supply the same consuming centre. The diversion of a current of trade is a delicate matter, it being essential that the new market should be as advantageous, both to buyers and sellers, as the original.

Account is taken of the distance by applying a scale of rates proportional to or varying with the distance. As we have already stated, the special rates applicable to certain producing districts or destinations have been abolished in the present day scheme of rates, as have also the standard station to station rates, introduced in order to enable the consignors to meet certain competition. But two classes have been allowed to stand, which according to Mr. Bloch should not be in a scheme for the unification of rates, being one relating to the unspecified intermediate stations (which applies to all the destinations included in a length of line, the same rate being operative between the two extremities) and one which compels the railway to apply the most advantageous rate, from the point of view of the consignor, of those corresponding to the various alternative rates. (In the case of the most indirect, this entails a very considerable reduction.)

The new scheme of rates, says Mr. Bloch, in that it abolishes all the special advantages granted in favour of agricultural industry and commerce, is without doubt a matter of fiscal policy, but it has the advantage of breaking down the barriers which formerly separated the various railways, and from this point of view it has been the first step in the direction of the unified working which the new railway regime wishes to realise. It is necessary, however, to somewhat relax the too hard and fast rules on which the French scheme of rates is based, as is claimed by all the trading community concerned. In this connection, Mr. Bloch examines the principles by which an investigation of the new rates should be governed, and shows how they are confirmed by experience which has already been gained.

It is often supposed that a reduction in rates is effective in fostering new classes of traffic and in developing existing traffic. Except in the case where the public derive immediate benefit from these reductions (such as postal services and passenger fares), this is not the case and it is the middle man who appropriates that which the railway has ceded. In order to reduce the price of a pound of food stuff by a half-penny, it would be necessary to reduce the cost of transport by 100 fr. per tonne, and no rate could bear such a reduction. The reduction in rates thus hardly affects the consumer (and it is for this reason that the increase has no appreciable effect on the cost of living, but it affects the dealers who handle large quantities and keep the additional profit for themselves. Thus it is that the official statistics for the market of La Villette show an appreciable reduction in the price of meat in 1921 as compared with 1920. If the consumer has not benefitted by the fall in prices, it is not on account of the rise in railway rates, as these have no bearing on the amount by which the prices charged in the butchers' shops exceed the wholesale prices at La Villette market.

A reduction in rates can only have this effect in the case of competition between sources of supply. Mr. Bloch quotes the reduction by about 40 % on the rates for the transport of wine from the South of France to Paris, which was made in 1893 in order to facilitate the sale of these wines after the phylloxera crisis when the market was flooded by their rivals from Spain, Italy, Algeria and Greece. The total tonnage arriving in Paris was not altered, but the consignments sent from the South of France by rail ousted to a large extent the sea borne foreign wines. Another example is the common rate adopted by the various railways for corn and cereals, which have been in force since 1892, and which has saved central France from an agricultural crisis by assisting home grown corn to compete with the foreign product imported through Marseilles. There is also a curious example in which the reduction of rates made in order to encourage manufacturers of lime to increase their output has resulted in a considerable profit from the traffic and in the agricultural development of the whole district. On the other hand, the adjustment of rates has afforded protection to the metal industry of central France, and to the mining industry of the Centre and South.

* * *

Dealing with the competition between the canals and the railways, Mr. Bloch has demonstrated that this could not exist were it not for the fact that the canals are protected, in the first place by being free of tolls, that is to say, the free use of a line of communication, which as a rule is more costly to establish than a railway, and also by the various conditions which are included in railway rates. The canals are handicapped by the slowness of their transport, their greater distance between the same points, by floods, droughts, frost and fogs, and by the impossibility of travelling by night, and finally by the necessity of transporting complete loads at a time. It is a great mistake to imagine that their speciality is the transport of heavy and inexpensive goods, as these yield them very small profit, in spite of the advantages which they enjoy, and therefore on the contrary they aim at carrying those classes of traffic which yield a larger margin of profit whenever they can make up their loads with the same, and during the war one might have seen the Belgian bargemen at Havre neglecting coal, grain and steel, and preferring to take cotton or coffee, without considering the country's requirements. When the railways had agreed to comply with the same rates as the inland waterways, but limiting this obligation to heavy goods of the last two classes consigned in complete boat loads, there was an outcry to extend the benefits of these rates to all classes of goods, and to reduce the tonnage condition to 10 t. per wagon.

It is often said that Germany encourages by preferential rates the transfer of goods from the waterways to the railways. This is a popular belief which has many times been disproved by those who have studied the question, especially by Mr. Marlio in this publication (10 September 1909). In 1902, Mr. Mange showed in the *Revue des Deux Mondes* that the transhipping port of Mannheim had been built by the Government of Baden in order to divert the Swiss traffic on to its own railways, to the detriment of the lines on the left bank of the Rhine. Mr. Haelling has just given a complete account of this, and extends it to the case of the ports of Ludwigshaven and Kiel, which are rivals of Mannheim and Strassburg. We have not omitted in reviewing his book (10 August 1921, p. 282) to call attention to these interesting remarks. The creation of these ports are episodes in the struggle between rival railways. As for competition between the railways and waterways, and

as for the protests of the latter against the railway rates, these are much the same in Germany as in France, and Mr. Bloch gives a typical example which occurred scarcely a year ago. In both countries the representatives of the waterways united to demand, without considering the interests of the general public, that the railway rates should be raised still higher.

Mr. Bloch proceeds to consider the interchange depots between the canals and railways which exist in large numbers in France, and states that their use is very limited. The canal depots appear to him to be more suitable for dealing with local traffic between the factories which spring up in their vicinity than for effecting important interchanges of traffic between the canal and railway. He then explains very clearly the difficulties, from a practical point of view, which are met with in applying to both methods of transport the system of common rates which exist between the railways. In the case of the latter, the division of the charges is fully guaranteed to all concerned by means of the common control; but how is this division to be made in cases where the charges have to be shared with the waterway? At the time when the new rules were brought into force, the railways were asked, as we have stated above, not to extend the benefits of all their common rates to the whole of the canal traffic, but to adopt common rates under certain conditions and guarantees with the canal companies who would agree to accept these, and also to submit to the control that is already imposed on the railways.

There is just as much misconception on the subject of combined rates between the railways and the mercantile marine, which it is supposed are largely adopted in Germany in order to assist their export trade, but one has only been able to quote two very special cases in which the Germans have applied such rates to their more important overseas trade. What is more, they have existed for a long time in France where their result has been practically nil. The impossibility of dividing the charges is due principally to the instability of marine freights (which have varied more than ever in the course of the last few years) these being the object of continual bargaining. This was very ably demonstrated a few years ago by Mr. Colson. Mr. Bloch shows, however, in what special cases and under what conditions combined rates may be useful, as for example in the transport of our colonial timber.

He then demonstrates the theory of export rates (reduced rates applicable between inland stations and ports or frontier stations) and takes as an example the traffic in brown paper for packing purposes. Dealing with the subject of export traffic, he cites the error committed in the past as regards Antwerp. Although before the war the Germans made every effort to develop their business at that important port, regardless of the interests of Bremen or Hamburg, every step has been taken to divert the French traffic, with the object of thus benefiting the port of Dunkirk. The recent concessions as regards the warehouse charges is evidence of a wider appreciation of the general interest of the country, and it is to be hoped that Antwerp will become, from a commercial point of view, a French port instead of becoming a German one.

The question of international interchange traffic leads Mr. Bloch to speak again with reference to the Berne Convention, the principal object of which is to apply to international railway traffic uniform regulations as concerns conditions of transport, responsibility and also as regards legal points. He then speaks of the great engineering works already carried out or projected in order to obtain railway communication between neighbouring countries

separated by natural obstacles. The two tunnels of Mont Cenis (1871) and Gothard (1882) give results which are less satisfactory than does the Simplon tunnel which, located between them, serves a limited area. The financial results of the Loetschberg tunnel ought to cause suggestions for new tunnels to be received with caution, the rise in cost has moreover rendered their construction impossible generally.

Mr. Bloch also deals with the schemes put forward for La Faucille, the Great and Small St. Bernard, Mont Blanc, and the line from Nice to Coni, which is now under construction. In connection with the proposed crossing of the Pyrenees, he makes this remark which is specially apt in the light of present events : « between France and Spain there is an obstacle more difficult to overcome than the Pyrenees, this being the customs duties by which the two countries strongly protect their own products ».

A tunnel under the straits of Gibraltar, and the construction of a railway as far as Dakar would allow the journey from Paris to Rio de Janeiro to be made in seven days, and to Buenos Ayres in eight (instead of three weeks), but this development is still in the far off future. This should not be the case as regards the Channel Tunnel, « an important and productive enterprise which is only prevented by the hesitation of the British Government ». However, even in England the scheme gains supporters every day. It has many in France, and the movement in favour of this great work of civilisation and peace extends every day in Belgium and Italy. One can now hope that the coming years will see its realisation.

Mr. Bloch, while discussing the factors which go to encourage or to hinder international interchanges of traffic, mentions the inconvenience caused by differences of gauge (Spain contemplates altering its gauge of 1.67 m. (5 ft. 5 3/4 in.) to the normal gauge of 1.435 m. (4 ft. 8 1/2 in.) and means of avoiding reloading by the use of wagons with changeable wheels and axles, the use of which is unfortunately hindered by the customs. He deals with the question of agents who collect and despatch goods in bulk so as to ensure complete loads, this system being much in vogue in Central Europe. This is economically a mistake, but is often advocated in this country. Whatever may be said, the efficient use of rolling stock is as good in France as in Germany, though in the case of the latter it is helped by the transport of coal, which is a considerable percentage of the total traffic. However, the French system of unified rates provides for transport in bulk, and thus to a certain degree compensates for the abolition of the special rates.

The use of private owners' wagons is limited to certain definite purposes and strictly governed by the regulations of the railway companies. An exception is made in the case of tank wagons and refrigerator wagons, the latter being used so as to give every possible facility to the frozen meat traffic.

* * *

As regards the fast goods traffic, the rates, provided these are not excessive, are not of great importance compared with the essential conditions of speed and regularity.

The parcels traffic is essentially that of small quantities, and in some ways is complementary to the slow goods traffic. The most important items are the perishable goods, and in this case especially the conditions of transport are of greater importance than the actual rates charged. As regards speed and regularity of this traffic, the French railways are far in advance of those of other countries, thus the export of perishable goods was, before the war, a considerable source of wealth in France, and without prejudice to the inland transport. In 1913, the total amount of

perishable goods arriving in Paris exceeded 800 000 t. per annum, or about 2 700 t. per working day, this being equivalent to 540 wagons containing 5 t. each and 18 fast goods trains of 30 wagons each. In order to encourage the producers to increase their output and the dealers to extend their business, the French railways have included in their regulations clauses which clearly define their responsibility in cases of delay. The foreign railways, while perhaps their rates are lower, do not accept responsibility to anything like the same degree. Thus for a consignment of fruit from Montauban to Paris, the amount of delay for which the railway accepts legal responsibility with the German regulations as regards fast goods traffic would be 106 hours, and 91 hours under the Italian regulations. It is 17 hours with the French.

Special rates at certain seasons have been made for fruit, vegetables and eggs from the South and cheese from Auvergne : examples such as these prove that it is good practice to reduce the rates in cases where the absolutely unified rate does not meet the requirements. The meat traffic is the subject of special study on the part of Mr. Bloch. He proves in the first place that the cost of transport has not a preponderating influence on the cattle traffic. The organisation of this traffic on fast freight trains presents serious difficulties and seriously hampers the regularity of running of passenger trains. The aim should be to replace the transport of live animals by that of frozen meat. This point was raised by Mr. Bloch before the war, but not much attention was paid to it. However, 50 000 t. of dead meat are delivered in Paris, that is a quarter of the total meat consumption of the capital. The war has given greater experience in the transport of meat, and has, to a certain extent, destroyed the prejudice against the consumption of chilled or frozen meat. It is recognised that in our country (France) the use of insulated wagons is all that is required to preserve meat which has been previously frozen. With the refrigerator or insulated wagons left in France by the American Army we have at our disposal about 2 300 wagons which are used for the transport of meat, fish, fruit, butter, etc. A new organisation of this traffic is being developed which includes cold storage warehouses installed at various places along the railways (of which special mention may be made of that of the Orleans Railway at Ivry station).

Mr. Bloch explains the efforts made by the railways in order to develop and increase the traffic in salt water fish, fresh water fish, milk and all forms of traffic which should be included in a properly organised system of refrigerated storage and transport. The management of the special rolling stock and cold storage depots is at the present entrusted by the railways (except in the case of the State Railway) to affiliated companies. This arrangement appears to be preferable to that in which this is directly carried out by the railway companies themselves.

Attention should be drawn to the educational campaigns instituted by the railways in order to develop the districts which produce the various perishable goods, as this enterprise is quite unique and without any parallel in foreign countries; these include demonstrations in packing goods, distribution of selected seeds and plants, demonstrations in pruning trees, visits of experts to the producing districts and to the important markets, publications and meetings to demonstrate the advantages of certain crops, and the methods of obtaining good results (endives, asparagus, medicinal herbs, fruit tress). This propaganda has also included methods of cultivation (use of irrigation), the preserved vegetable and jam industry, farm products, dairy produce, poultry and eggs, butter, cheese making, etc. It has already had

and will certainly continue to have very satisfactory results in developing natural industries, and should have every support from the producers, from the business community and from the public authorities who it has only to be hoped will not hinder it too much by rules and regulations.

* * *

Turning to the passenger traffic, Mr. Bloch insists on the necessity of easy travel for business men who have to make long journeys to the great commercial centres, so as to ensure comfort and economy of time. This also raises the question of cross country connections across France, and that of the communication of Switzerland with our sea ports, which ought to be able to compete with those of the North Sea, Hamburg and Antwerp. It will be necessary for this reason to join Limoges and Saint-Germain-des-Fosses by a new line suitable for fast and heavy traffic.

We then pass to the consideration of international passenger traffic and the running of a service of packet boats in connection with the railway, thus prolonging as it were their lines as far as the ports of Northern Africa. Similar arrangements are already in existence between France and England, and between Italy and Sicily. The question was raised in 1916 by the Midi Company who offered to construct and run fast boats between Port Vendres and Algiers and Oran. The idea of such combined services appears to be very natural. It secures for the railway, not only the profit from the seaborne transport, but also produces an extension of their traffic. This scheme however has not yet matured. The service to Morocco affords an example of combined fares (from Marseilles or from Bordeaux to Casablanca) between the railways and steamboat companies.

The much discussed question of prepaid mileage tickets is fully dealt with by Mr. Bloch, who shows that where these have been introduced abroad, it has been done through force of circumstances, and that they give rise to serious inconvenience, as has been found by experience. They are a nuisance to the railway company, give rise to frauds, and can only be used by persons in a position to pay in advance relatively large sums of money and occasion a large amount of formalities. The season tickets at half fare give equivalent advantages without raising the same objections.

The new system of reduced fares for large families consisting of tickets, the price of which is reduced according to the number of children under 18 years of age, and which apply to the parents as well as to the children, has, during the last two years, proved a great success. It may be looked upon as a bonus to parents for each additional child.

The very liberal scale of personal luggage allowed in France entails considerable expense to the railways, and which is largely transmitted to the passengers in various ways, such as delays with all their consequences, and by part of the additional cost occasioned by the traveller with luggage being borne by others who have nothing but a hang bag. There is certainly a flaw in the decision of the Court of Appeal, which has decided that all kinds of objects, such as ploughs, garden implements, hawkers' packs, foodstuffs of all kinds, should be accepted as luggage and carried free. Thus one is tempted to agree with Mr. Peyrabon, Controller General of the commercial side of the railways to the Minister of Public Works, who, in the course of a series of articles, which are full of interesting and frequently original ideas, published in the *Génie Civil* (26 November and 3 December 1921, 21 January 1922) proposes to drastically curtail the free transport of luggage.

Mr. Richard Bloch terminates his review of the problems connected with

the commercial working of the railways by making mention of the prices charged for commercial travellers' season tickets. This form of traffic, up till recently, has developed to such a degree as to be a serious hindrance to passenger trains. It was interrupted by the war, but these tickets have again been recently issued, although under conditions which, while being sufficiently liberal to satisfy the public, avoid the inconveniences.

Mr. Bloch concludes by pointing out that all these problems must be solved by common sense and not by hard and fast rules, and this has been somewhat overlooked in establishing unified rates, which now require to be adjusted. A system of rates should be capable of always adapting itself, with slight adjustments as required, to the constantly varying conditions of industry and commerce. The last few items of Mr. Bloch's treatise are given verbatim and are worthy of careful consideration.

« Attention has been drawn to a number of examples of the various kinds of co-operation that the railways, especially in France, strive to give to their customers. It is very evident that their prosperity depends on the wealth of the districts which they serve, and they ought to spare no effort to develop this wealth. The public should be shown and should clearly understand that it is dealing with not purely profit making organisations, but rather with organisations with which they have a common interest. These have no doubt the legitimate desire to ensure their receipts, but with this natural reservation, they are, in view of their widespread resources, information, statistics and staff, capable of effectively assisting the efforts of merchants and manufacturers in the search for new markets, or in the development of existing trade, thus increasing their common prosperity and that of the whole country. »

The reduction of existing rates, considered as a whole, is certainly desirable. But is it possible? One can take no such steps at the present without still further increasing the enormous deficit of the railways and thus hampering the service to the detriment of the public, who require that all the means of transport should operate satisfactorily and meet all their needs. We are suffering from the terrible damage caused by the war, and whatever may have been the magnificent results achieved on the railways since the armistice, this is still the case, despite the improvements and the steps taken to ensure our economic recovery. A healthy financial position is absolutely necessary to our railways in order that they may be on a sound basis, carry out necessary works and electrify their lines. The leading American railway publication *The Railway Age*, in one of its recent numbers (31 December 1921) contains an article entitled « The railway situation and trade generally », in which it clearly demonstrates « that any premature reduction of rates in the end costs the traders more than they save ». This is not a paradox, it is the actual truth, and applies in France as much or more than in the United States. However, it is evident that the rates should be reduced as much as possible. This will not be achieved by prolonging, as has just been done, the subsidy of 720 fr. which becomes less and less justified by the cost of living, nor by continuing to pay the railwaymen wages considerably higher than those of private industries which are already making adjustments, nor in perpetuating the absurdity of the eight hour day, which is in itself responsible for a large part of the deficit for 1921.

MISCELLANEOUS INFORMATION

[625 .144.2]

1. — The proper elevation of the outer rail,

By CHARLES WEISS.

(*Railway Maintenance Engineer.*)

Common practice in the United States of America is to equalize the pressure of equipment on both rails, by elevating the outer rail in accordance with the theoretical formula of mechanics for centrifugal force, namely, $\frac{MV^2}{R}$. This formula has been reduced for various speeds and degrees of curvature, and is found in almost every handbook on the subject. Most authorities recommend that the figure V for speed to be used, should be the maximum that high speed passenger trains are permitted to make over that section of track.

It is believed that the blind and almost universal application of this theory is responsible for many of the deplorable rail conditions so noticeable on the curves of many railroads. This malady of « excessive superelevation » means an annual waste of thousands of tons of rail and contributes in no small degree to many accidents.

In the first place the practice outlined attempts to secure safety for the very extreme and rare condition of highest speed, while the other extreme or even the average condition of ordinary freight trains is ignored. The tractive effort and the corresponding speed is reduced by many factors. The grade, proximity of signals, stations, water towers, fuel stations, and other local characteristics all modify it. Trouble with equipment, congestion on the road and weather conditions decrease the number of trains that might otherwise be included in this small percentage of highest speed trains. Some of the local characteristics may not be known or fully appreciated until operated over for a considerable period. But the fact remains that to get the elevation that is just right for a very few trains, means getting too much difference for the great majority of heavy engines.

In many cases it will be found that instead of being increased, the safety has actually been jeopardized by high elevation. The important point in this connection is uniformity. Without it no track is safe, with it, other conditions being equal, there is no danger of accidents. Derailments occur not because of the amount of elevation, but because of the variation in the average amount over a very short distance, causing cars to rock from side to side until they force themselves off the track.

A further disadvantage of excessive elevation is the cost of maintenance. It is a matter of common knowledge that this figure increases with the degree of curvature. It is equally true that it increases with the amount of elevation. Since most of the trains passing around very much tilted track grind on the lower rail, that rail very soon wears out. There is also some danger of it being turned over. In addition to the rail, the ties and other elements of the track structure being similarly subjected to uneven pressure, are comparatively soon worn out. The cost being higher and the work more difficult, it is but reasonable to expect to find greater variations in the surface as the elevation is increased, so that the deciding factor of safety is unquestionably in favor of low elevation at the curve.

« One of the worst features of excessive elevation is the fact that it tends to increase itself automatically. In other words, if the superelevation to begin with is such that most

of the weight bears on the lower rail, it is but a natural consequence for that rail to be hammered down harder into the ballast than the other rail. The original difference is then increased by the amount this rail is so driven down. This rate of change seems to be an accelerating one, accompanied by a deterioration of ballast and pumping joints.

« Short curves are difficult to spiral, especially if of short radius. The change in elevation may become dangerous if the curve is only a few hundred feet long and an attempt is made to raise the outer rail very much. A train of only moderate length will extend onto both tangents, and the distortion caused by the curvature and elevation may cause cars to uncouple or to jump the track. This danger is decreased while the riding qualities are improved if the superelevation is kept at a minimum value. »

The effect on tractive resistance, while slight as a rule, is nevertheless worthy of consideration. This is particularly true in this country, where we superelevate the outer rail entirely, as compared with the European practice of dropping the inner rail and raising the outer rail equal amounts. It means that we are increasing the grade on one rail, and in the case of a maximum tonnage train of slow freight, this may be sufficient in certain extreme cases to either stall the train or to cause the engine to burn the rails. In any case it adds to the resistance of the train and increases the wear on the track.

While admitting that the formula and tables referred to may be well adapted to tracks used solely by one class of trains, such as high class passenger, the writer believes that far better results can be obtained by the use of a few simple rules at the outset, and then to observe the curve under traffic, making corrections that seem desirable. This should be done in any case, but it is thought that fewer changes will be necessary in the method suggested than if the formula be employed. It is, of course, possible to change the formula by introducing certain constants to make it conform to true conditions, but the advantage would be very doubtful.

The practice suggested is as follows :

1° For freight tracks, where the maximum speed is about 35 miles per hour, elevate the outer rail 1/2 inch per degree of curvature, with a maximum superelevation of 4 inches;

2° For tracks used by both freight and passenger trains, elevate the outer rail 2/3 inch per degree of curvature, with a maximum superelevation of 5 inches;

3° For high speed tracks, elevate the outer rail 3/4 inch per degree of curvature, with a maximum elevation of 6 inches.

Having applied these rules, the track should now be observed for correction in two ways :

1° Note how trains ride around the curve. If at normal speed they lurch towards the outer rail the superelevation is insufficient and should be increased. If they grind on the lower side the elevation is excessive and should be reduced;

2° Observe the wear on the rail. If the head of the high rail shows excessive wear, the elevation is too small and should be increased. If the lower rail is worn most and gives evidence of flattening out and of grinding action, it indicates that the superelevation is excessive and should be reduced.

A matter of equal importance is to properly locate the difference in elevation on the run-off or spiral of the curve. It should conform to the sharpening of the curve, and should be accurately and clearly marked at every change.

Every curve is a problem in itself, and while no formula can be devised to meet all special conditions, it is nevertheless believed that the procedure outlined above will give more economical, safer and simpler results than is obtained by the application of the theoretical formula.

[625 .235 (.75)]

2. — Illinois Central steel suburban coaches.

Figs. 1 to 10, pp. 1256 to 1260.

(*Railway Mechanical Engineer.*)

The Illinois Central has recently received from the Pullman Company 20 new steel suburban coaches, which have been placed in service in Chicago, the design of which has been influenced in numerous details by the prospective electrification of this road within the Chicago terminal district. The cars are completely equipped for steam train service, in which they are now operating, and have been designed primarily for trailer service after electrification has been completed, although the car bodies are of sufficient strength to be equipped with motor trucks, and other electrical apparatus, should this later seem desirable. The weight of the cars equipped for steam operation is about 92 100 lb.

At present the cars are equipped with steam heat and with axle generator and battery equipment for electric lighting; this equipment in both cases follows the standard of the road for passenger coaches in main line service. The conversion for electric service will consist of the substitution of electric heaters for the present steam heat equipment and the removal of the axle generator equipment, the current for lighting then being obtained from the power source. The vestibules have been arranged to facilitate the installation of multiple unit control apparatus, brake valve, gages, etc., and with this in view the hand brake staff and handle have been placed on the left side instead of the right side of the vestibule platform.

The cars have a coupled length overall of 72 ft. 2 in. and are 60 ft. 6 1/2 in. long over the body end sills. A seating capacity of 84 is provided for by 17 transverse seats on either side of the car and four longitudinal seats 4 ft. 9 in. long, one on either side at each end of the car. Sliding doors are used throughout. Those at the ends of the seating compartment close from either side toward the center, while the end and side vestibule doors are each single units, the former opening toward the left while the latter slide back into the side walls of the car body. The end doors of the car and the vestibule side doors provide a clear opening of 4 feet in each case, while the vestibule trap doors are 3 ft. 4 in. in width. The floor plan shows the proposed arrangement of the control apparatus for electric operation and the way in which the right side of the vestibule will be closed off to form the motorman's compartment.

In working out the seating arrangement, particular attention has been given to provide ample room between the seats and ample height of back for the comfort of passengers. No ends are provided on the seats, in order that the passengers may enter quickly and leave them quickly and conveniently. The width of the aisle at the seat end is about 31 inches, increasing to 36 inches at the edges of the seat backs. This width is considered ample to permit two persons moving in opposite directions to pass in the aisle without difficulty.

The interior finish is steel throughout, with the exception of the single sash, which are of mahogany. Above the side lights the finish is in white, including the fixtures. The sides and the seat ends are finished in mahogany color.

Details of construction.

With the exception of the longitudinal sills and a few details of the vestibule ceiling construction, the frame members are practically all of pressed steel.

The center sills are 9-inch, 15-lb. channels placed back to back 16 inches apart. At the bottom they are reinforced with 4-inch, by 3-inch, by 1/2-inch angles, the long flanges of which project toward the center of the car. These sills are 69 ft. 3 in. long and at the ends are framed into steel buffer castings. At the top they are reinforced with a 1/4-inch plate 21 inches wide and 64 ft. 8 1/2 in. long. Bot-

Fig. 1. — Illinois Central suburban cars, adapted for electric operation.

Fig. 2. — Interior view, showing open-end seats.

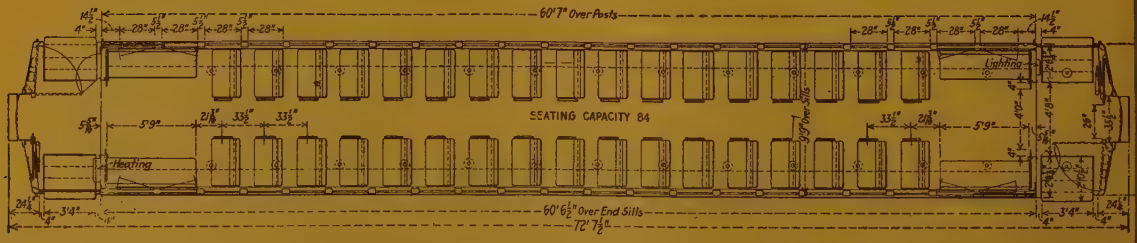


Fig. 3. — Floor plan, showing provision for motorman's compartment.

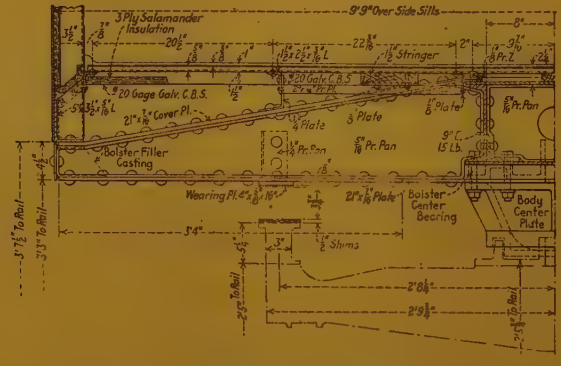


Fig. 4. — Underframe section at bolster.

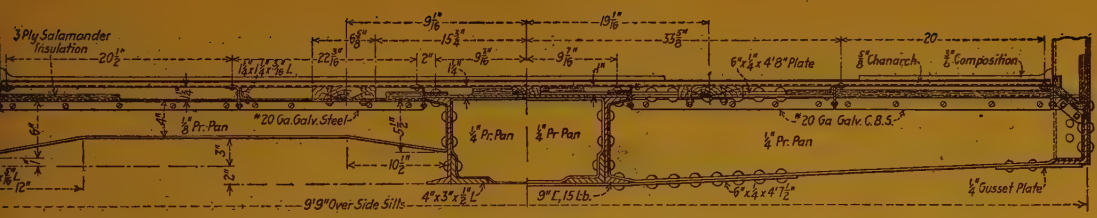


Fig. 5. — Transverse sections of underframe at floor beam and cross bearer.

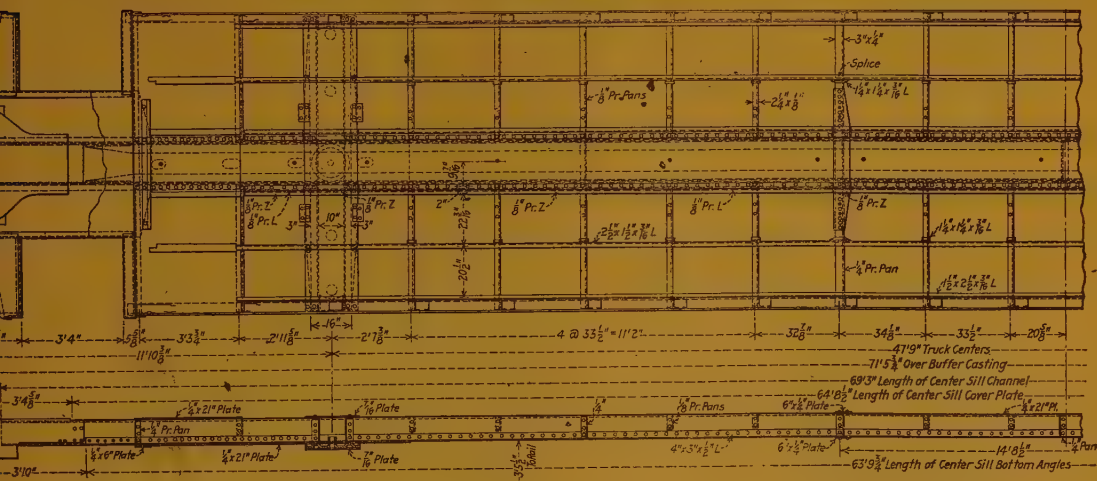


Fig. 6. — Underframe design : Illinois Central suburban coaches.

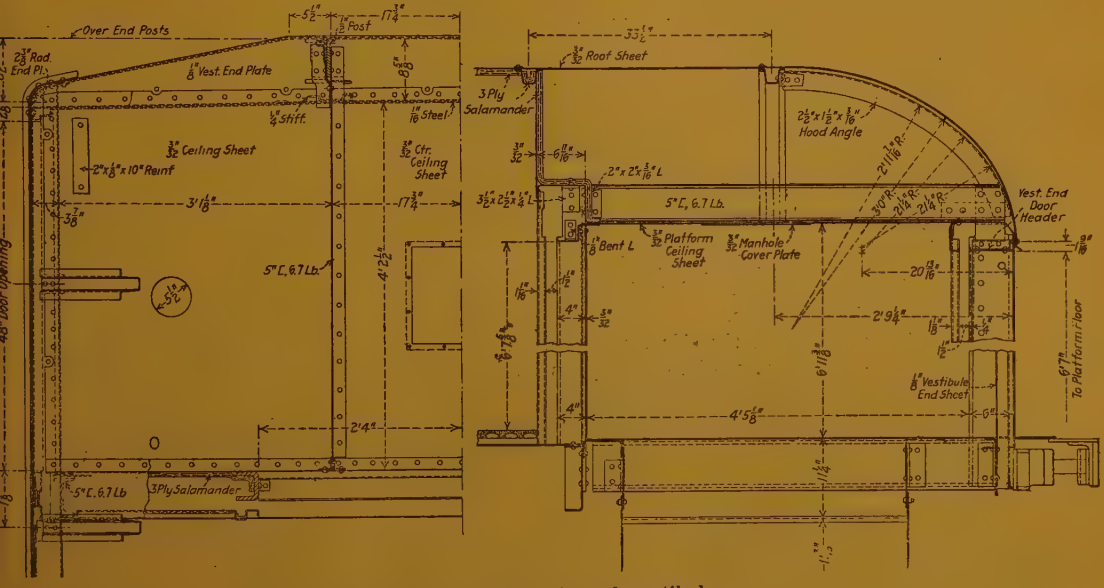


Fig. 8. — Sections through vestibule.

tom cover plates of the same dimensions, each 8 ft. 5/8 in. long, extend towards the ends of the car from points about 2 ft. 6 in. inside of the center line of the body bolster.

The lateral members of the underframe are all pressed steel pan sections. The bolster is formed of two of these sections of 5/16-inch material with flanges 3 inches deep, spaced 10 inches back to back with fillers between the center sills. They are finished with top and bottom cover plates of 7/16-inch material, 21 inches in width, which extend continuously from side sill to side sill. A filler casting below the center sills brings the lower face of the bolster 2 1/2 inches below the bottom of the sills. The lower face of the bolster is horizontal while the top tapers from a depth 12 3/16 inches over the center sills to a depth of 4 1/2 inches at the sides of the car. This brings the ends of the bolsters directly under the 5/8-inch by 3 1/2-inch side sills.

There are two cross bearers, each 7 ft. 4 1/2 in. from the transverse centre line of the car. These are each made up of three single pressings of 1/4-inch material, one on either side of and one between the center sills. The three units are joined with 1/4 inch top and bottom tie plates about 48 inches long. The floor beams, one of which is provided at each vertical frame member, are of 1/8-inch material.

Longitudinal stringers of 2 1/2-inch by 1 1/2-inch by 3/16 inch angle section are placed over the floor beams, one on each side of the car 33 5/8 inches from the centre line. The rectangular openings between the longitudinal and transverse members are closed with flanged sheets of No. 20 galvanized steel, painted, the flanges of which are secured to the frame members with 1/4-inch stove bolts. At the sides these sheets are bolted to the vertical flanges of 2 1/2-inch by 1 1/2-inch by 3/16-inch angle floor supports riveted to the inside faces of the side posts.

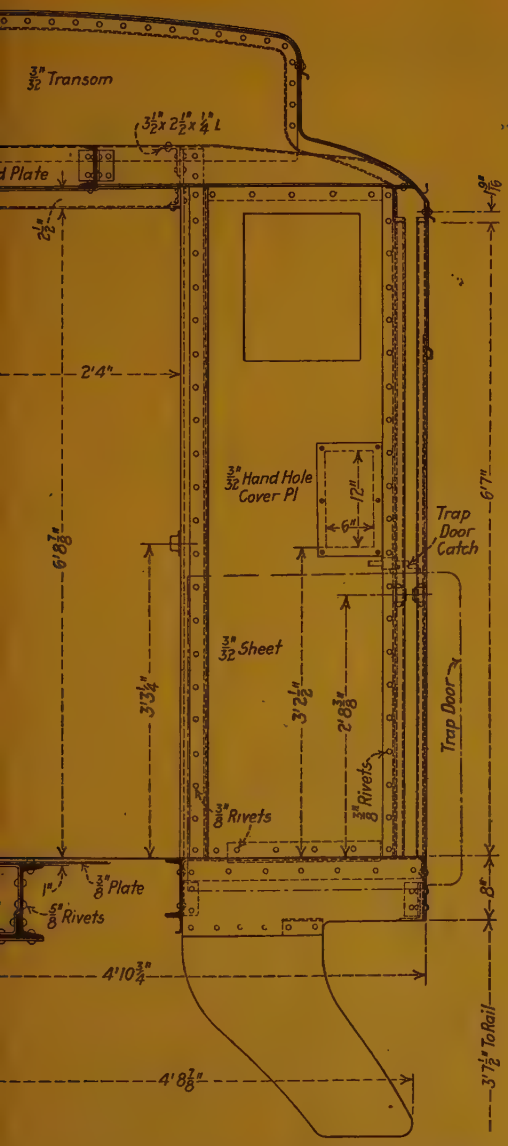
The vertical members of the side frame are double channel sections arranged to form posts 5 1/2 inches deep by 3 1/2 inches in transverse width. These posts are framed into the angle side sills at the bottom and into side plates of special pressed section at the top. The carlines are of flanged channel section, the ends resting directly on the side plates.

The outside of the car is finished with 1/8-inch girder plates and a 4-inch by 1/2-inch belt rail below the windows. The pressed steel sash rests of 1/8 inch material are placed between the side posts, which are located 2 ft. 9 1/2 in. between centers. The sash rests are 29 3/4 inches above the floor and are formed so that the outer flanges are flush with the outside girder plates. The belt rail forms a splice for the sash rests and the side girder plate. Above the windows the sides of the car are closed on the outside by a letter board about 18 inches in width.

The principal members of the vestibule constructions are 6-inch channel vestibule end posts of 1/2-inch pressed steel, 4-inch channel body door posts of the same material and body end posts of 5-inch, 6.7-lb. channel section secured to the inside of the side construction. The lower ends of the vestibule end posts are framed into the steel buffer casting and at the top are secured to the ends of 5-inch, 6.7-lb. channels extending longitudinally just above the vestibule ceiling to the bulkhead at the end of the car body. These channels are spaced 17 3/4 inches on either side of the longitudinal center line of the car while the faces of the body door posts are 2 ft. 4 in. on either side of the center line. The inner ends of the longitudinal channels and the upper ends of the body door posts are secured by corner plates to a transverse member of pressed steel which in effect forms a deep box girder across the car at this point. Other details of the vestibule construction are shown on one of the drawings (fig. 7).

The car body is insulated with three-ply insulation throughout, laid against the outside of the body walls. The floor is finished with 3/8 inch of composition material laid on corrugated pressed steel supports.

The cars are carried on four wheel trucks with cast steel frames and the usual type of equalizing arrangement, fitted with 33-inch rolled steel wheels mounted on axles with 5-inch by 9-inch journals. The pedestals are cast integral with the truck frames. The bolsters are of cast steel and are fitted with



7. — Details of vestibule framing of Illinois Central steel suburban coaches.

roller side bearings and seperate center plates, the interior surfaces of which are finished and fitted with finished bronze liners. The trucks have clasp brakes.

The trucks are fitted with a device for adjusting the coupler height by raising the spring plank, shown in sections on the truck drawing. The device consists of a spring plank hanger pin or yoke provided with four bearing faces the radial heights of which are progressively increased. Progressive adjustments are made by turning these pins or yokes to bring the next higher space under the spring plank and substituting filler blocks with flanges of suitable depth.

Door operating mechanism.

All doors on these cars are of steel construction. The double doors at the ends of the car body are geared so that they operate together. They are arranged to lock both in the open and closed position.

The vestibule side doors are operated by air engines, one for each door, taking air from a reservoir under the car maintained at main reservoir pressure by direct connection with the locomotive. Each end of the car is fitted with one of these reservoirs which has sufficient storage capacity to permit the operation of the doors 10 or 12 times after the locomotive has been cut off. These reservoirs are directly connected to the main reservoir of the locomotive by a 3/4-inch train line. No signal air line is provided as automatic electric signals are used in suburban service.

The door operating engines are located under the longitudinal seats at the ends of the car. The operation of the air valves of this mechanism is electrically controlled by double lever switches which are mounted in cast iron boxes, secured to the outer faces of the vestibule door posts at both ends of the car. There are two levers, both arranged to lock in the neutral position, one for opening and closing the door and one neutral. As a further safety feature there is a collapsible arm on the engine shaft so that the door can be opened about 6 inches from its closed position. Each switch box controls both of the doors on one side of the coach, an arrangement which permits one guard to operate all of the doors on two cars. In event of an electrical failure the air valve may be operated by hand. In case

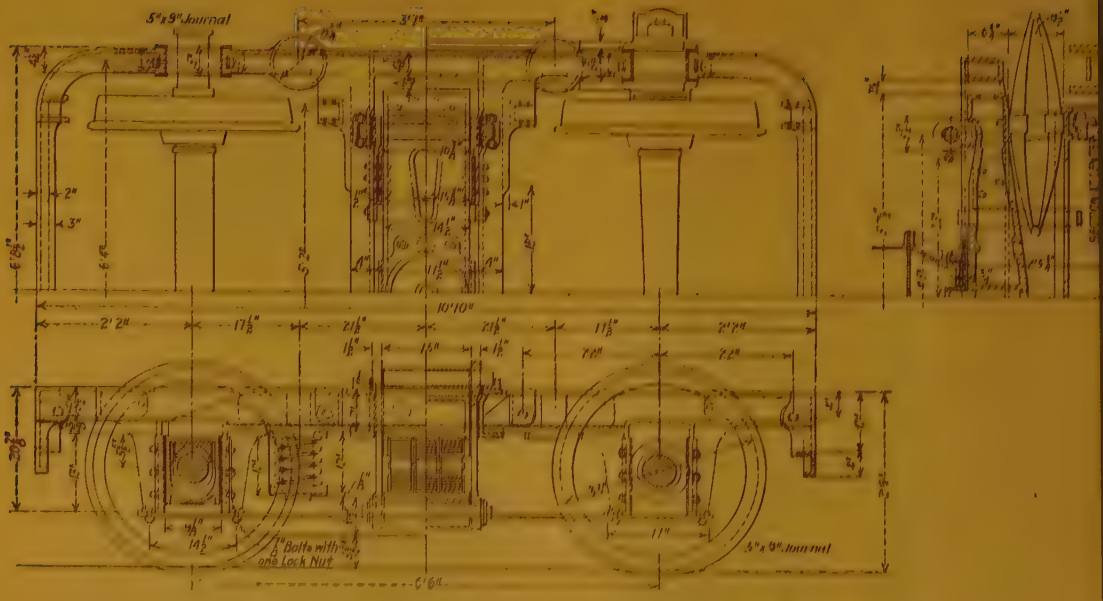


Fig. 9. — Cast steel truck under Illinois Central suburban coaches.

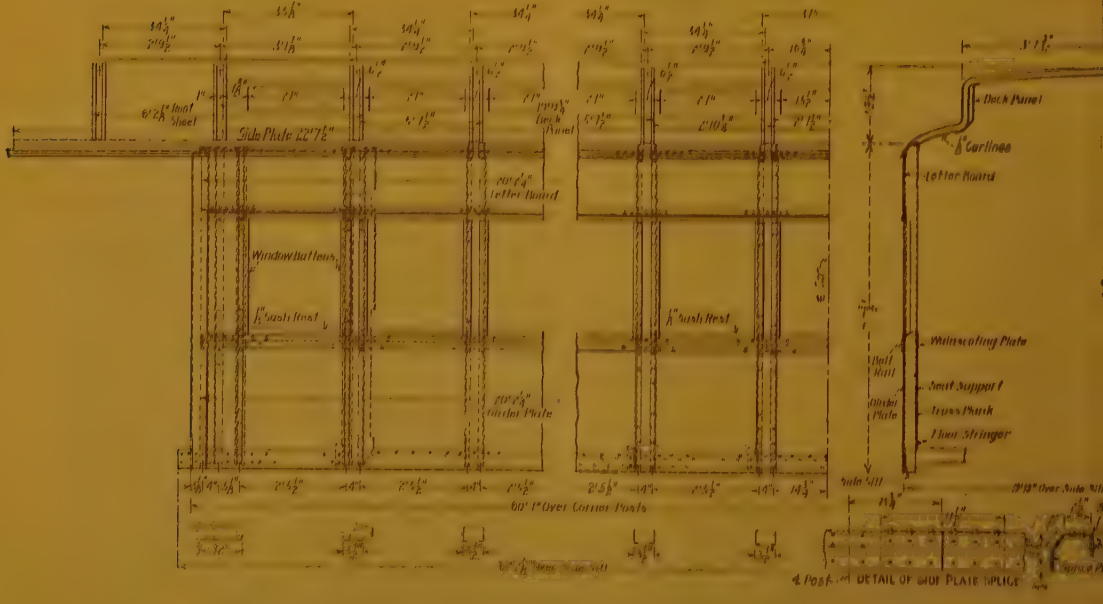


Fig. 10. — Side frame construction of Illinois Central suburban coaches.

a door is closed on an obstruction which prevents further movement it automatically opens about 36 inches, then reverses and moves towards the closed position again. This movement is kept up automatically until the obstruction is removed. An electric contact mounted on the edge of the door and protected by a flexible rubber casing, causes this action.

A feature of considerable interest in connection with steam operation is an electric starting signal operated automatically by the closing of the doors. A green light mounted in the cab of the locomotive is connected to a series circuit carried back through the train by electrical connectors between the cars. This circuit is broken by the opening of any vestibule side door in the train and is closed only when all of the doors are closed. Closing the doors thus causes the lighting of the green lamp in the locomotive cab, which serves as a starting signal following station stops. The circuit for the automatic starting signal receives its energy from the headlight generator of the locomotive.

[621 .132.8 & 621 .335]

3. — New development in locomotive practice.

A new condensing turbine electric locomotive, which is shortly to be tested in main line service.

Fig. 11, p. 1262.

(*Railway Gazette.*)

As we have on previous occasions mentioned, increased attention is being given at the present time to what may be termed « alternatives to the steam locomotive » in its accepted modern form. As a rule, when thought is given to this question, electric traction is the alternative mostly considered, and little or no doubt can exist that in that direction railway propulsion will find a large measure of development in the future. On the other hand, it does not do to ignore other possibilities, especially where conditions of an interim but by no means altogether temporary description arise and have to be provided for, and it is in this connection, perhaps, that such locomotives as that illustrated herewith are most likely to find favour, at any rate until they have established their value from the traffic point of view on a basis of all-round efficiency and with due regard to economical working.

During the latter part of last year we were permitted to examine the Ramsay turbine locomotive during its construction at the Scotswood Works of Sir W. G. Armstrong, Whitworth & Co., Limited, Newcastle-on-Tyne, on which occasion the originator, Mr. D. M. Ramsay, managing director of the Ramsay Condensing Locomotive Company, Limited, of Glasgow, explained the principal features of the design to us. A very great deal of ingenuity, time and thought have been expended upon this locomotive, which may be regarded as the second practical attempt made in this country to introduce the condensing turbine locomotive with electric transmission, the first one being the Reid-Ramsay locomotive built by the North British Locomotive Company, Limited, Glasgow, and tried on the Cowlairs Incline, Glasgow, in the year 1910.

In locomotives of this type the principal, and indeed, the primary object, is to economise in fuel and water, and a superheater boiler with, in this case, a total heating surface of 1 453 square feet is provided for generating steam for actuating the main and auxiliary turbines. A condenser of novel design is installed into which the exhaust steam from the turbine is discharged through a large diameter pipe, being expanded down from boiler pressure to a vacuum of 27 1/2 inches, the condensate being drawn off from the condenser by a rotary extracting pump and returned to the well, from which a feed pump delivers the water into the boiler, thus completing the cycle.

The Ramsay locomotive is, in effect, two

Fig. 11. — The Ramsay condensing turbine electric locomotive, built by Sir W. G. Armstrong, Whitworth & Co., Limited.

separate units which, when coupled together, to a large extent resemble a locomotive with its tender as in ordinary practice. As a matter of fact, however, both units form separate engines coupled together. The front one, both as regards the boiler and framing, differs but little from accepted locomotive practice, with the exception, of course, that the features of the cylinders, reciprocating parts, etc., are replaced by a turbo-generator, this being supplied by the Oerlikon Company, of Zurich. The main turbine is of the impulse pressure compounded multi-stage type, connected through a flexible coupling to a three-phase generator capable of sustaining a 25 % overload for half an hour. This generator is separately excited by an auxiliary turbine-driven direct-current generator The three-phase generator supplies power to four three-phase slip-ring motors arranged in two groups on the front and rear parts of the locomotive respectively. The two motors of each group are bolted to a common stretcher carrying a countershaft to which the motors are geared. The power is then transmitted from the countershaft to the six driving wheels on each engine unit by coupling rods in the ordinary manner. Each of the motors is capable of developing 275 H. P.

The rear engine incorporates the coal bunker and cooling water tank, as well as the condenser and its appurtenances. The condenser is of the evaporative type supplied with air by a fan at the rear of the engine. The steam tubes of the condenser are arranged in the form of a cage, which is caused to revolve in water at slow speeds and through which the air is impelled by the fan in a radial direction over the tubes.

The boiler is hand fired and fitted for forced draught. The driver manipulates the locomotive by means of a master controller placed in the cab.

The leading particulars are as follows :

Length over-all.	69 ft. 7 in.
Length, wheelbase	59 ft. 4 in.
Length, rigid wheelbase.	16 ft. 4 in.
Weight on driving wheels, average .	18 tons.
Driving wheel diameter	4 feet.
Height from rails to centre of boiler.	10 ft. 3 in.
Width, maximum.	8 ft. 11 in.

Weight of front engine	67 tons 5 cwt.
Weight of front engine, light	63 tons 5 cwt.
Weight of rear engine	63 tons 10 cwt.
Weight of rear engine, light	48 tons 3 cwt.
Total weight, including 2 200 gallons of water for cooling purposes and 4 tons of coal	130 tons 15 cwt.
Total heating surface with superheater	1 453 square feet.
Grate area	28.4 square feet.
Boiler pressure	200 lb. per square inch.
Superheat	300° Fahr.
Adhesion weight	108.5 tons.
Tractive force	22 000 lb.
Ratio of adhesion to tractive force	11.05.
Turbo-generator	890 kw. at 3 600 revolutions and 27 1/2 in. vacuum, voltage 600.
Gauge	4 feet 8 1/2 in.

The locomotive has been sent to Horwich and will be tested under the supervision of Mr. George Hughes, chief mechanical engineer of the London & North Western Railway, in accordance with the running conditions. It was subjected to a preliminary test in the builders' yards at Newcastle before being sent to Horwich.

[621 .335 (.83)]

4. — Electric freight locomotives for Chile (1).

Figs. 12 and 13, p. 1264.

(*Railway Age.*)

Work on the fifteen electric road freight locomotives for the Chilean State Railways is nearing completion. The cabs for the first eight of the road freight locomotives have been delivered by the Baldwin Locomotive Works to the Westinghouse Electric & Manufacturing Company for the installation of the equipment. There will also be seven switching locomotives.

The road locomotive has a cab of the box type, carried on two articulated trucks, each having three driving axles with direct geared motors. The estimated weight is 226 000 lb. It will operate at 3 000 volts direct current.

This locomotive has a rating of 1 680 H. P. at 3 000 volts and will be able to develop a maximum of 3 200 H. P. for short periods. With natural ventilation the locomotive will deliver for one hour a tractive effort of 27 950 lb. at a speed of 22.6 miles an hour at 3 000 volts. The continuous capacity of the locomotive with forced ventilation is 20 880 lb. tractive effort at 24.8 miles an hour. The maximum speed is 40 miles an hour.

(1) The Chilean electrification problem was outlined in the 21 January 1922, issue of the *Railway Age*, page 216, and the passenger locomotives were described in the issue of 4 March 1922, page 527.

The general dimensions and estimated weights of the locomotive are as follows :

TABLE I.

Dimensions and weights of road freight locomotives.

Track gage	5 ft. 6 in.
Length over buffers	49 ft. 10 in.
Length over cab	38 ft. 0 in.
Total wheelbase	37 ft. 0 in.
Rigid wheelbase	13 ft. 9 in.
Height, top of rail to cab roof	12 ft. 7 in.
Height, top of rail to clerestory	13 ft. 10 in.
Width over cab sheets	10 ft. 0 in.
Height of coupler	41 in.
Wheel diameter	42 in.
Weight of complete locomotive	226 000 lb.
Weight of mechanical parts	140 000 lb.
Weight of electrical equipment	86 000 lb.
Weight per driving axle	37 670 lb.

The road locomotives will operate over the 116-mile route between Santiago and Valparaiso and the 28-mile branch between Las Vegas and Los Andes. The heaviest grade is 2.25 % for 12 miles from Llai Llai to La Cumbre. This is known as the Tabon grade. The maximum curvature is 11°. There are six tunnels in the electrified zone.

The present main line freight trains average

550 short tons. They are operated with a single steam locomotive, except on the heavy 12-mile grade southbound, and on a northbound grade of 6.8 miles. On these two sections a steam helper is now used to maintain speeds of from 10 to 14 miles an hour.

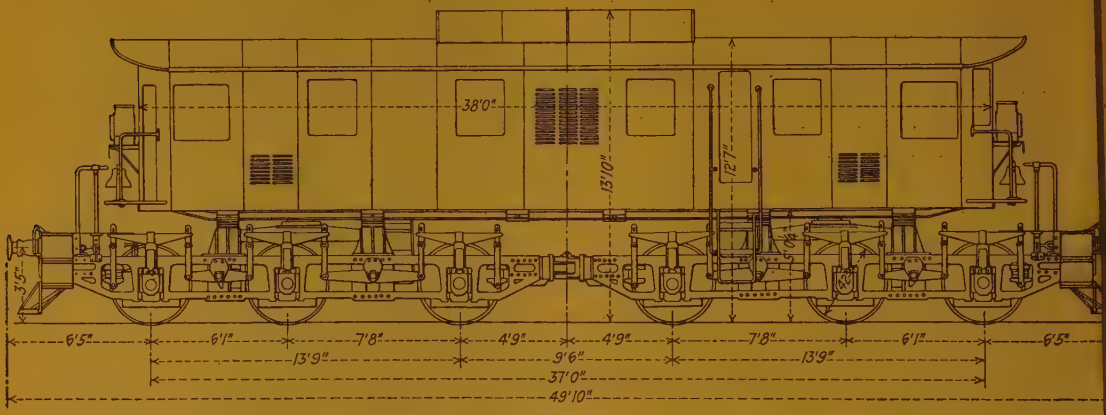


Fig. 12. — Side elevation of road freight locomotive.

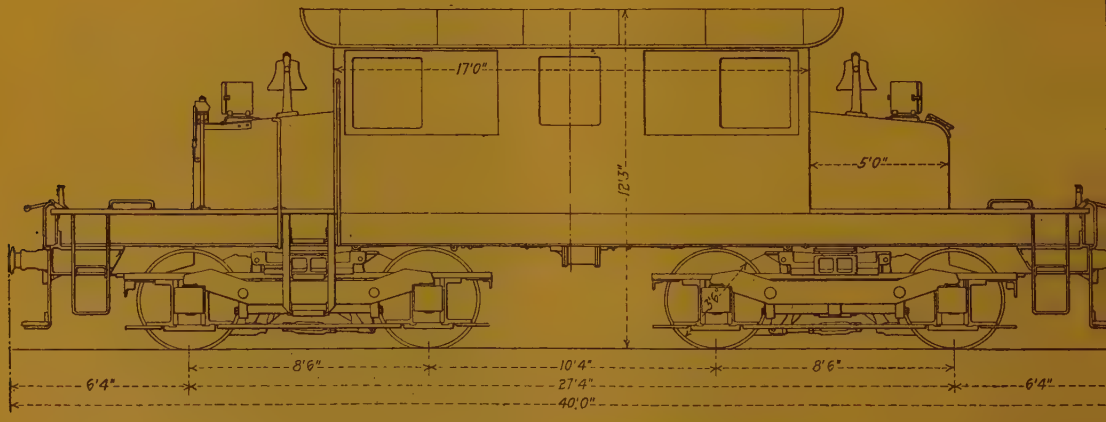


Fig. 13. — Side elevation of electric switching locomotive.

One electric locomotive will haul a trailing load of 770 short tons in either direction between Valparaiso and Santiago without assistance except on the Tabon grade. On level tangent track the speed with such a load will be 35 miles an hour. The average running speed on the Tabon grade will be approximately 24 miles an hour. The time saved by the elimination of delay to take fuel and water and by the higher running speed will shorten the time of a trip from four to five hours in each direction.

These locomotives are equipped with Continental spring buffers and M.C.B. couplers, arranged to take attachments for chain couplers temporarily. The two six-wheel trucks are connected at the inner ends by a mallet hinge. The bar-type cast steel side frames are located outside of the wheels and are connected by cast steel bumpers and crossties. The semi-elliptic

driving springs over the journal boxes on each side are connected to one another by equalizer beams. The ends of each set of three driving springs connected thus are attached to the side frames through coil springs.

The 38-foot box-type cab, including an engineman's compartment in each end and a central equipment compartment, is carried on center pins located approximately over the midpoint of each rigid wheelbase. One center pin is restrained both longitudinally and laterally and the other in the lateral direction only, which permits free longitudinal movement of the cab relative to one truck.

The locomotives are equipped with Westinghouse air brakes, which are standard for the Chilean Railways. The air brake is interlocked with the regenerative brake so that the latter may be supplemented by service application of the train brakes, if desired, without applying the air brake to the locomotive drivers.

Current is collected by spring-raised, air-lowered pantagraphs, controlled by compressed air and arranged to be mechanically locked in the lowered position. Individual switches mounted in banks establish the main circuit connections. Each switch is a complete unit in itself and may be removed without disturbing adjacent switches. Compressed air controlled by electro-magnetic valves is used to operate the switches. For certain circuits where no current is broken and for low voltages, cam switches are used. These also operate by compressed air controlled by electro-magnetic valves. The cam group comprises a number of switches mounted on a single shaft, connected through a rack and pinion to a double-acting air piston.

Each axle of the locomotive is driven by a motor, wound for 1 500 volts and insulated to operate two in series on 3 000 volts. The nominal rating of this motor on short field is 280 H.P. at 155 amperes and 1 500 volts. Field control is secured by the use of two separate field windings on the main poles. The motors are geared directly to the axles with a ratio of 3.94 to 1. The gear used is of the flexible type.

A motor-generator set provides low voltage power to compressors, blowers, control equipment and lights. This set has a single frame and two armatures carried by a common shaft. The 3 000-volt motor is a bi-polar double-commutator machine. The continuous rating of the generator is 35 kw. at 92 volts.

A master controller is located in each engineman's compartment to provide double-end operation, the same master controller being used for both motoring and regenerative braking. This controller provides 50 control notches in acceleration.

For regenerative braking, the main motor armatures are arranged for the same combinations as when motoring and the motor fields are separately excited by the motor-generator set. The range of speed in regenerative braking will be from 8 to 30 miles per hour.

Switching locomotives.

The switching locomotives will be the last ones built. The cab is of the steeple type and is carried on two swivel trucks. Two motors are mounted on each truck driving direct through helical gears. The estimated weight is 136 000 lb. The control is arranged for double-end operation.

The nominal rating of this locomotive is 560 H. P. With 3 000 volts, and natural ventilation, the tractive effort for one hour is 19 600 lb. at a speed of 10.6 miles per hour and the continuous capacity is 11 400 lb. at 12.7 miles per hour. With 25 % nominal adhesion the starting tractive effort is 34 000 lb. The maximum speed is 35 miles an hour. For short periods the equipment is capable of developing 1 000 H. P. In view of an expected increase in traffic these locomotives have been designed to handle trains of 1 200 short tons in yards with level tracks.

The following table gives the general dimensions and estimated weights of the locomotive:

TABLE II.

Dimensions and weights of switching locomotives.

Track gage	5 ft. 6 in.
Length over buffers	40 ft. 0 in.
Length over central cab	17 ft. 0 in.
Length over hoods	27 ft. 0 in.
Total wheelbase	27 ft. 4 in.
Rigid wheelbase	8 ft. 6 in.

Height, top of rail to cab roof	12 ft. 3 in.
Width over cab sheets	10 ft. 0 in.
Height of coupler	36 7/16 in.
Wheel diameter	42 in.
Weight of complete locomotive	136 000 lb.
Weight of mechanical parts	86 000 lb.
Weight of electrical equipment	50 000 lb.
Weight per driving axle	34 000 lb.

The trucks are of the rigid bolster equalized type with rolled steel frames located outside of the wheels. A center pin is located at approximately mid-length of each rigid wheelbase. The central cab has an engineman's stand in each end and control apparatus centrally located and suitably protected. Buffers, couplers and air brake equipment are duplicates of those on the road locomotive. The control equipment also comprises apparatus similar to that already described for the road locomotives and the pantagraph is of the same type.

The four motors are of the series type wound for 1 500 volts and insulated for operation two in series at 3 000 volts. Each motor has a one-hour rating of 140 H. P. at 75 amperes and 1 500 volts.

The motor-generator set, to supply power for the compressor motor, lights and control circuits, has a two-part frame, each part containing two bearings in which runs a common shaft carrying two armatures, one a 1 500-volt motor (insulated for 3 000 volts) and the other a low voltage generator. With 3 000 volts applied to the motor, the generator will deliver 22.5 kw. at 92 volts.

The main control resistance, connected ahead of all motors, is designed with ample capacity for frequent, heavy accelerations and for a reasonable amount of emergency operation with one pair of motors cut out. The number of accelerating steps assures moderate changes in tractive effort in starting, which in turn tends to minimum wear and tear on the locomotive and rolling stock.

[385 .113 (.45)

5. — The working of the Italian State Railways during the year 1919-20 (1).

The working of the Italian State Railways during the financial year 1919-20 was considerably affected by the serious economic, social and political events of the post-war period, and the complicated difficulties experienced were without precedent.

The length of the system had been increased by 18.94 % as compared with the period immediately preceding the war. On the 30 June 1920 it comprised, 15 720 km. 141 m. (9 768.213 miles) of standard gauge and 805 km. 542 m. (500.550 miles) of narrow gauge lines, whereas on the 30 June 1914 the corresponding figures were 13 665 km. 886 m. and 228 km. 328 m. (8 491.735 miles and 141.879 miles). On the other hand, the revenue had either diminished, or had not increased in proportion to the increase in the growth of the system.

The general agitation in the labour world affected the employees, who on several occasions struck, interfering with the service and paralysing the traffic. The most serious of the strikes, which lasted from the 20 to the 29 January 1920, led, amongst other things, to the general reduction of working hours, and this in its turn had a serious effect both on the transport service and on the efficiency output of the staff.

As a result of the introduction of new conditions of service, not entirely completed during the financial year 1919-20, and of the increase in the length of the system, the total staff increased, between the 30 June 1914 and the 30 June 1920, 46.60 %, namely from 147 387 to 216 075; but this increase affected only the workmen, who increased from 89.07 to 91.73 % of the total, or from 9.61 to 12.61 employees per kilometre (from 15.47 to

---

(1) Preface to the official report just issued : *State Railways. Report for 1919-20, Rome 1921, War Service Polygraphic Department*, pp. XVI-124 text and pp. 125-203 appendices.

20.29 per mile) of line; whereas the administrative staff decreased from 1.02 to 0.69 % of the total, and from 0.11 to 0.09 % per kilometre (from 0.18 to 0.15 % per mile), the remainder of the staff decreasing from 9.91 to 7.58 % of the total, and from 1.07 to 1.04 per kilometre (from 1.72 to 1.67 per mile).

The lines and accommodation, which during the war could only be developed in the military zone, remained stationary on the rest of the system, and were not able to afford any relief to the problems caused by the unusual congestion of traffic. Nevertheless, in spite of the high cost of material and labour, the development of these lines and accommodation was actively taken in hand, either by the improvement, repair, or restoration of existing lines, or by the construction of new lines. Considerable progress has also been made in the electrification of certain sections.

The condition of the rolling stock was greatly depreciated owing to the excessive use made of it during the preparation for and the actual period of the war. Owing to the rolling stock handed over by the enemy after the war, the stock per kilometre had slightly increased, *viz.*, (between the dates already mentioned), from 0.386 to 0.415 locomotives (from 0.621 to 0.668 locomotives per mile), from 0.277 to 0.285 luggage vans (from 0.446 to 0.459 luggage vans per mile) and from 7.534 to 9.215 (and from 12.125 to 14.830 per mile), for wagons (passenger coaches on the other hand decreased from 0.726 to 0.695 [from 1.168 to 1.118 per mile]). There was however a considerable increase in the two years under comparison in the percentage of stock under or awaiting repair, *viz.*, from 16.6 % to 27.6 % with locomotives, from 24.7 to 39.6 with passenger coaches, from 27.3 % to 34.7 % with luggage vans, and from 10 % to 16.2 % with wagons. The effect of the shortage of locomotives compared with the traffic to be dealt with, especially bearing in mind the poor condition of those available, was really serious.

The problem of the repair of rolling stock was the most difficult to be solved. As a result of well known general causes, the output of private firms, especially in the case of those building new rolling stock, was very poor, although every possible encouragement was given. On the whole, however, considerable progress was made with repairs.

Serious difficulties were experienced in the running of trains because of the irregular supply (which at certain periods became an absolute shortage) of fuel for locomotives, and because of the poor quality of that which it was possible to obtain.

For reasons which were due to outside causes quite independent of any action of the administration — such as, to name the most important, the numerical addition to the staff and the increase in wages granted to them, the depreciation of money values, the raising of prices, exchanges and freight charges — working expenses increased enormously and, for the first time (preceding financial years closed either with a small credit balance, with the exception of 1914-15 which had a debit balance of about 21 million l.) there was the large deficit of 859 751 496 l. 98, while the ratio of working expenses to receipts increased from 81.25 to 137.49 %. This does not take into account (nor do the statistics given below) the lines worked on behalf of other administrations of the State beyond the pre-war boundaries and those in the colonies.

Traffic receipts increased (always compared with 1913-14) from 0 l. 152 to 0 l. 515 per axle-kilometre, and from 42 l. to 126 l. per kilometre worked. The increase of traffic and the successive raising of rates contributed towards this increase of receipts. The rates were raised for the first time as from the 1 December 1919, and again as from the 6 April 1920; consequently the effect of the increases on the financial year under consideration was only partial.

The cost of the working staff has increased from 283 643 000 to 1 270 661 000 l., and the average daily wage per employee from 1 l. 92 to 6 l. 50.

The fuel required for the locomotives — which the Italian railways are in the unfortunate position of having to obtain from foreign countries — has entailed increased expenditure of from 76 055 000 to 977 993 000 l., or from 0 l. 154 to 0 l. 815 per axle-kilometre.

The average cost of coal has risen from 36 l. 46 to 379 l. 84 per tonne.

However, in view of the difficulties encountered, and the insufficient revenue previously referred to, the technical working and traffic results given below, in respect of the whole standard gauge system (excluding only the Dalmatian lines) deserve attention.

Military transport was little by little replaced by ordinary traffic. There were only 46 886 667 tr.-km. (75 455 182 tr.-miles) of passenger and mixed trains as against 72 973 849 tr.-km. (117 437 545 tr.-miles) in 1913-14; but a comparison of the receipts, taking into account the increases in rates, shows for 1919-20 an increase of about 40 %.

The average daily loading of goods and cattle was 11 378 wagons with 119 041 t. of goods, or 0.742 wagon with 7 t. 76 of goods per kilometre of the system, corresponding to the loading of 3 788 136 wagons with 39 727 332 t., as compared with 5 026 295 wagons and 41 421 872 t. in 1913-14. The average length of journeys however has increased as a result of the new condition of trade from 170 to 246 km. (from 105 to 153 miles), so that the kilometric-tonnes carried, which give the truest idea of the work done, have increased from 7 060 885 000 to 9 795 568 000, *i. e.*, from an average of 519 119 to 638 564 per kilometre (of 835 423 to 1 027 647 per mile) of the system. The total mileage of goods wagons has increased from 2 190 162 487 axle-kilometres to 2 421 018 170 (from 1 360 928 466 axle-miles to 1 504 378 129); and the empty mileage of the same wagons have decreased from 469 498 965 to 430 788 310 axle-kilometres (from 291 738 504 to 267 684 283 axle-miles).

Better use has been made of the trains than before the war, and the average load per axle has increased from 4 t. 267 to 5 t. 043; the average weight of trains has increased from 235 t. 1 to 313 t. 6 for steam traction, and from 191.6 to 295 for electric traction; the average composition of trains has increased from 23 to 30 axles for passenger trains, and from 45 to 46 axles for goods trains.

The consumption of fuel per locomotive-kilometre has increased from 13 kgr. 61 to 20 kgr. 16 (from 48.29 to 71.53 lb. per locomotive-mile), the inferior quality of the fuel causing a greater quantity to be used, whilst the weight of the trains has also increased.

Accidents were considerably fewer than in the previous year.

Finally, transport (especially as regards delays of passenger and goods trains, damage, and losses) has been affected by the numerous disturbing influences already referred to, and the crippled resources with which an increased traffic has had to be dealt with. There has been considerable increase of theft. The total expenditure on compensation has increased by about 33 million l., *i. e.*, about eight times more than in 1913-14, due of course in part to the higher cost of goods.

Such in brief are the results of working, and the special conditions under which the said working has been carried on.

L. G. Maccallini,
Engineer.

[338. (06.111]

APPENDIX :
List
of
iliated administrations.

OFFICIAL INFORMATION

OF THE

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

RULES AND REGULATIONS

Objects, headquarters and constitution of the Association.

ARTICLE 1. — The object of the International Railway Congress Association is to facilitate the progress and development of railways by the holding of periodical Congresses and by means of publications. The headquarters of the Association are at Brussels.

ARTICLE 2. — The Association is composed of State Railway Administrations, or of Administrations of a railway conceded to, or worked by, public initiative in countries which have joined the Association.

It is composed of the Railway Administrations included in the list shown in appendix of the present rules.

The Governments of the countries to which the Association extends may also join the Association.

The list of these countries may be altered by a decision of the Congress as laid down in the revised rules by article 20 which follows.

Permanent Commission.

ARTICLE 3. — The Association acts through a Permanent Commission composed of members nominated according to article 6 and sitting at Brussels.

ARTICLE 4. — The Permanent Commission can, by a postal vote, giving a majority of three quarters of the total membership, provisionally alter the list of countries belonging to the Association subject to ratification by the next Congress. It has power to arrange for the admission of Railway Administrations who apply, subject to a report prepared by a member nominated by the President.

Only those Administrations may be admitted whose principal business is the running of railways worked by mechanical traction of a length of at least 100 km. (62 miles) in active service, or conceded to a public company and worked in the public interest.

In fixing the minimum of 100 km. (62 miles) mountain sections, where special means of haulage are employed, may be calculated at double their actual length.

All railway companies admitted after the final constitution of the Association passed by the Congress held in Rome in 1922, which no longer comply with, and which have ceased to fulfil the above conditions, or go into liquidation or fail, will cease *ipso facto* to form part of the Association. The same shall apply to any railway company which does not pay its subscription for more than two years.

The admission of an Administration in a State which itself is only provisionally included in the Association, under the terms of the

first paragraph of this article, remains provisional until the admission of the State itself is confirmed.

ARTICLE 5. — The Commission shall organise the Congress meetings, prepare an agenda for discussion, be responsible for their preliminary treatment, edit and publish reports for the discussions, draw up a balance sheet, fix, subject to article 17, the amount of the annual subscriptions, be responsible for the finances, and set on foot any investigations and issue any reports or other publications which will, in its judgment, further the objects of the Association.

ARTICLE 6. — The Permanent Commission shall be composed of ex-presidents of the sessions of the Congress, ex-officio members and elected members, the number of which shall be fixed by each Congress.

The elected members shall be, as far as possible, chosen to represent the different nations. Under no circumstances shall any one nation have more than nine elected members.

One third shall retire at each Congress and shall be eligible for re-election.

Members who have ceased to hold office under an adherent government, or with a railway administration which qualified them at the time of their election, shall cease to be members of the Permanent Commission. It shall be the duty of such a member at once to inform the president when he retired. The Permanent Commission may, upon the application of five members, with the consent of the majority of all its members consulted by letter, ask him to remain until the next Congress.

The Commission shall always have the power to complete its number by co-opting delegates of the participating administrations and adherent governments. In this case a final election shall be made at the following Congress.

When the place of meeting of a Congress has been fixed, the Permanent Commission shall have power to co-opt as temporary members representatives of the country in which the Congress is to be held.

ARTICLE 7. — The Permanent Commission shall elect from among its members a president and two vice-presidents at its first meeting after each Congress of the Association.

The president and the chief vice-president shall be chosen from the Belgian members.

The Commission shall appoint a general secretary, a secretary-treasurer and secretaries. As such they shall have the right to attend the sessions in a consultative capacity.

The Commission shall be summoned by the President when the business of the Association requires it, but in any case at least once a year.

A meeting may be held when demanded by any five members.

Questions shall be decided by the votes of the majority of members present. If the votes are equal the Chairman shall have the casting vote.

Minutes shall be kept of the proceedings of the Commission. Nine members shall form a quorum.

If at a first meeting this number is not present the meeting shall be adjourned for not longer than one month, when it shall then be considered valid whatever may be the number of members present.

ARTICLE 8. — The Association shall be represented in Courts of Justice and in all civil actions by the president, or in the event of his being unable to attend, by the general secretary of the Permanent Commission.

Executive Committee.

ARTICLE 9. — At its first meeting after a Congress the permanent Commission shall nominate three of its members, who, with the president and the vice-presidents of the Commission, shall form an Executive Committee.

The president of the Permanent Commission shall also be president of the Executive Committee.

The general secretary, the secretary-treasurer and the secretaries of the Commission shall be members of the Committee, and shall have the right to take part in discussions, but not to vote.

The members of the Executive Committee shall hold office for a period equal to the interval between two Congresses. They shall be eligible for re-election.

The Executive Committee shall meet at the instigation of the president on his own authority or on the requisition of three members.

The Committee shall be responsible for the management of current affairs and for financial business; also for superintending and managing investigations, reports and publications; for the editing of the *Bulletin* and for the care of the library and archives. It shall decide as to printing in whole or in part the reports and other documents submitted to a Congress, the circulation of which it regards as necessary to facilitate the discussions. It shall be the duty of the Committee to furnish members of the Association with such special information as they may require.

The Committee shall have the right to appoint and to dismiss the staff.

The carrying out of the decisions of the Committee is entrusted to the president and the general secretary.

Congresses.

ARTICLE 10. — At each Congress the Association shall fix the time and place for the following Congress.

The Permanent Commission may alter such arrangements under exceptional circumstances.

ARTICLE 11. — The following shall have a right to attend the meetings :

1° The members of the Permanent Commission, the secretaries and the secretary-treasurer;

2° Delegates appointed by the railways and Governments comprised in the Association. These must belong to the regular and permanent staff of the delegating Administration;

3° The secretaries of sections, and the reporters appointed by the Permanent Commission or by the Executive Committee to report on the items on the agenda.

ARTICLE 12. — The participating Railway Administrations shall be entitled to nominate up to ten delegates according to the mileage of their system in the following ratio :

One delegate for lines of not more than 200 km. (124 miles);

Two delegates for lines of 200 to 500 km. (124 to 311 miles);

One additional delegate for each additional 500 km. (311 miles) or fraction thereof above 500 km. up to 3 000 km. (1 864 miles);

One additional delegate for each additional 1 000 km. (621 miles) or fraction thereof above 3 000 km. (1 864 miles).

The adherent governments may also nominate ten delegates as a maximum in the proportion of one delegate for each 200 fr. subscription up to 1 000 fr. and one additional delegate for each 500 fr. over 1 000 fr.

The maximum figures quoted above do not include those members who take part in the Congresses in accordance with the 1st and 3rd paragraphs of article 11, and whom the participating administrations or adherent governments include amongst their delegates.

All delegates participate in the Congresses with equal rights.

ARTICLE 13. — At the opening of each Congress, the officers of the Permanent Commission shall hold office temporarily, until the Congress has elected its own officers as follows:

1° One or more honorary presidents and vice-presidents;

2° One president;

3° Presidents of sections elected as explained in article 14;

4° One or more general secretaries and one or more assistant secretaries.

The delegate nominated first by each government shall be an ex-officio vice-president.

All officers shall be appointed for the duration of the session.

The election shall take place according to the rules laid down in article 16, paragraph 6. The duties of the officers shall be those laid down by standing orders adopted by deliberative assemblies for the conduct of their proceedings.

After the appointment of the officers, the Congress shall resolve itself into sections, ac-

cording to the arrangements of items on the agenda submitted by the Permanent Commission.

A member may enter his name for more than one section.

The Congress may also appoint special committees to investigate certain questions.

ARTICLE 14. — Each section or committee shall appoint its own president, its own chief secretary, and its secretaries. The presidents of sections shall be officers of the Congress in virtue of their position.

The sections and the special committees shall cease with the termination of each session.

ARTICLE 15. — The discussions of the Congress shall be confined to the questions which are decided upon by the Permanent Commission, due regard being had to the wishes of the preceding Congress and its sections.

The Commission shall receive suggestions from the participating and constituent bodies. A reporter appointed by the Commission shall prepare a brief outline of each question without expressing conclusions, and also a summary of the contents of the documents which have reached him.

No question shall be discussed at a general meeting without having been first considered by a section or special committee.

ARTICLE 16. — The discussions shall be conducted in French or in the language of the country in which the Congress is held. Speeches in any other language shall be translated into French.

The minutes and reports shall be drawn up in French, but speakers on demand shall be entitled to have their original words reproduced.

The officials of the respective sections shall draw up an abstract of the discussions setting forth the various opinions expressed in the section. After receiving the approval of the section these abstracts shall be submitted to the general meeting. They shall then be inserted in the minutes after having been completed by the addition, if necessary, of any new opinions expressed at the general meeting itself.

The Congress shall not vote except on questions of management or organisation.

On these special questions, the votes of the majority of the members present shall be taken by members rising in their places. If there is any doubt the votes shall be counted. A roll call shall not be held except at the request of not less than twelve members.

Subscriptions and auditing of accounts.

ARTICLE 17. — The expenses of the Congresses, of the Permanent Commission and of the Executive Committee shall be covered by:

1° The annual subscriptions of members;

2° Subsidies and other casual receipts.

The annual subscription shall consist of :

a) In the case of adherent governments, an amount fixed by themselves;

b) In the case of participating administrations, a fixed sum of 200 fr. Belgian currency, plus a sum proportionate to the mileage of the system. This variable sum shall not exceed 50 centimes Belgian currency per kilometre; the actual rate to be fixed by the Permanent Commission.

The financial year shall begin on the 1 January.

ARTICLE 18. — Payment of the subscriptions shall entitle the participating administrations and adherent governments to receive free, as many reports of the proceedings as the number of their delegates.

Other publications of the Association shall be sent to the subscribing administrations in numbers based upon their mileage, in conformity with article 12, augmented by one.

ARTICLE 19. — The Permanent Commission shall present to each Congress a report on the financial position. The Congress shall appoint two auditors to pass the accounts.

Revision of the constitution, dissolution and liquidation.

ARTICLE 20. — Every proposal for a revision of the rules must be submitted to the Permanent Commission, with reasons in support of

it, at least three months before the date fixed for the opening of the session, so that the Commission may bring it to the knowledge of the members of the Association at least one month before that date.

The proposition cannot be discussed at a full meeting of the Congress unless it has been agreed to either by the Permanent Commission, or if twenty-five participators or adherents desire that the question shall be discussed.

In the first case, it shall be discussed on the report of the Permanent Commission, in the second case on the report of a special committee.

ARTICLE 21. — Adherent governments and participating administrations constituting the Association pledge themselves to promote the meetings of the Congress and the work of the Permanent Commission.

ARTICLE 22. — The Association may be dissolved only by a three quarters majority, on a postal vote from the participating administrations, each one having a number of votes equal to that of the delegates to which it is entitled.

ARTICLE 23. — In the event of dissolution, the Permanent Commission shall have authority to arrange the liquidation.

By its agency the assets of the Association are to be distributed among works conforming with the objects of the Association or among philanthropic works in connection with railways.

ARTICLE 24. — In no circumstances shall participating administrations and adherent governments, who for any reason have ceased to belong to the Association, have any claim on the assets of the Association.

LIST OF AFFILIATED ADMINISTRATIONS.

NAMES OF THE ADMINISTRATIONS.	Kilometres.	OFFICES.
ARGENTINE (REPUBLIC).		
I. — *Lines of the State.*		
Chemins de fer de l'Etat	6 151	Buenos-Aires.
II. — *Private lines.*		
Buenos Ayres Great Southern Railway	6 278	London.
Buenos Ayres Western Railway	3 028	London.
Central Argentine Railway	5 319	London.
Entre Rios Railways	1 175	London.
Chemin de fer de Rosario à Puerto Belgrano	800	Paris.
Chemins de fer de la province de Santa-Fé	1 911	Paris.
BELGIUM.		
a) **Continent.**		
I. — *Lines of the State.*		
Chemins de fer de l'Etat	4 640	Bruxelles.
II. — *Private lines worked by the State.*		
Chemin de fer de Braine-le-Comte à Gand	65	Bruxelles.
Chemin de fer d'Eecloo à Bruges	28	Bruxelles.
Chemin de fer de Tournai à Jurbise et de Landen à Hasselt	46	Bruxelles.
III. — *Private lines.*		
Chemin de fer de Chimay	61	Chimay.
Chemin de fer de Malines-Terneuzen	68	Saint-Nicolas.
Chemin de fer du Nord français (lignes Nord belges)	170	Liége-Longdoz.
IV. — *Secondary lines of the State.*		
Société nationale des chemins de fer vicinaux	4 095	Bruxelles.

NAMES OF THE ADMINISTRATIONS.	Kilo-metres.	OFFICES.
V. — *Secondary private lines.*		
Société générale de chemins de fer économiques	116	Bruxelles.
Railways économiques de Liége-Seraing et extensions	20	Liége.
Compagnie belge de chemins de fer et d'entreprises	300	Bruxelles.
VI. — *Other companies.*		
Compagnie internationale des wagons-lits et des grands express européens	(1)	Bruxelles.
Compagnie auxiliaire internationale de chemins de fer	(2)	Bruxelles.
b) **Colony.**		
Chemin de fer du Congo	400	Bruxelles.
Chemin de fer du Bas-Congo au Katanga	750	Bruxelles.
BOLIVIA.		
BRAZIL.		
Compagnie des chemins de fer de l'Est brésilien	1 934	Paris.
Great Western of Brazil Railway	1 617	London.
CHILI.		
Antofagasta (Chili) and Bolivia Railway	1 318	London.
Nitrate Railways	631	London.
Taltal Railway	290	London.
CHINA.		
I. — *Lines of the State.*		
Chemins de fer de l'Etat :		
Ligne de Pékin-Hankow	1 200	...
Ligne du Lung Hai	1 800	...
II. — *Private lines.*		
South Manchuria Railway	2 979	Tokyo.
Compagnie générale de chemins de fer et tramways en Chine	551	Bruxelles.

(1) 4 664 passenger-axles, 576 freight-axles.
(2) 2,584 freight-axles.

NAMES OF THE ADMINISTRATIONS.	Kilo-metres.	OFFICES.
COSTA-RICA.		
Costa-Rica Railway	306	London.
CUBA.		
DENMARK.		
I. — *Lines of the State.*		
Chemins de fer de l'Etat	2 401	Copenhague.
II. — *Private lines.*		
Chemin de fer privé d'Aalborg	259	Aalborg.
Chemin de fer de l'Est de Seeland	47	Copenhague.
Chemin de fer de la Fionie méridionale	216	Odensée.
Chemin de fer de Lolland-Falster	104	Copenhague.
DOMINICA (REPUBLIC).		
EGYPT.		
Chemins de fer de l'Etat	3 181	Le Caire.
ECUADOR.		
SPAIN.		
Chemins de fer andalous	1 703	Malaga.
Chemins de fer catalans (réseaux de la Compagnie du chemin de fer central catalan, du chemin de fer du Nord-Est de l'Espagne et du tramway ou chemin de fer économique de Manrésa à Berga)	140	Liége.
Chemin de fer Central de Aragon	302	Bruxelles.
Chemins de fer de Madrid à Cacérès et au Portugal et Ouest de l'Espagne	777	Madrid.
Chemins de fer de Madrid à Saragosse et à Alicante . . .	3 663	Madrid.
Chemins de fer de Medina del Campo à Salamanca	77	Madrid.
Chemins de fer de Medina del Campo à Zamora et de Orense à Vigo	297	Barcelone.
Chemins de fer du Nord de l'Espagne	3 692	Madrid.
Mines et chemins de fer de Utrillas	127	Saragosse.
Great Southern of Spain Railway	168	Aguilas.

NAMES OF THE ADMINISTRATIONS.	Kilometres.	OFFICES.
UNITED STATES OF AMERICA.		
American Railroad Association	3 218	New York.
Atlanta & West Point Railroad and the Western Railway of Alabama	352	Atlanta, Ga.
Baltimore & Ohio Railroad	7 170	Baltimore, Md.
Bessemer & Lake Erie Railroad	349	Pittsburgh, Pa.
Buffalo & Susquehanna Railroad Corporation	407	Buffalo, N. Y.
Central of Georgia Railway	3 083	Savannah, Georgia.
Central Vermont Railway	863	St. Albans, Vt.
Chicago, Peoria & St. Louis Railway	378	Springfield, Ill.
Delaware & Hudson Company	1 258	New York.
Delaware, Lackawanna & Western Railroad	1 577	New York.
Elgin, Joliet & Eastern Railway	340	Chicago.
Erie Railroad	3 634	New York.
Hocking Valley Railway	552	Richmond, Va.
Illinois Central Railroad	7 725	Chicago.
Kansas City Southern Railway	1 347	New York.
Lehigh & New England Railroad	325	Philadelphia, Pa.
Lehigh Valley Railroad	2 251	New York.
Long Island Railroad	634	New York.
New York Central Railroad Company	5 954	New York.
New York, Chicago & St. Louis Railroad	842	Cleveland.
Norfolk & Western Railway	3 573	Roanoke, Va.
Pennsylvania System	16 949	Philadelphia, Pa.
Philadelphia & Reading Railway	2 546	Philadelphia.
Pittsburgh, Shawmut & Northern Railroad	338	St-Marys, Pa.
Richmond, Fredericksburg & Potomac Railroad	132	Richmond, Va.
St. Louis Southwestern Railway	2 538	St. Louis, Mo.
Southern Railway	10 560	Washington, D. C.
Staten Island Rapid Transit Railway	55	New York.
Ulster & Delaware Railroad	208	Kingston, N. Y.
Wabash Railway	3 980	New York.
FINLAND.		
Chemins de fer de l'Etat	4 224	Helsingfors.
FRANCE, ALGIERS, TUNIS AND COLONIES.		
a) **France.**		
I. — *Lines of the State.*		
Chemins de fer de l'Etat	9 002	Paris.
Chemins de fer d'Alsace et de Lorraine	1 969	Strasbourg.

NAMES OF THE ADMINISTRATIONS.	Kilo-metres.	OFFICES.
II. — *Main lines.*		
Chemins de fer de Ceinture de Paris	158	Paris.
Chemins de fer de l'Est	5 027	Paris.
Chemins de fer du Midi	4 081	Paris.
Chemins de fer du Nord	3 805	Paris.
Chemins de fer d'Orléans	7 793	Paris.
Chemins de fer de Paris à Lyon et à la Méditerranée	9 795	Paris.
III. — *Secondary lines.*		
Chemins de fer du Beaujolais	91	Villefranche (Rhône).
Chemins de fer du Cambrésis	120	Paris.
Chemin de fer de Chauny à Saint-Gobain	15	Paris.
Chemins de fer des Côtes-du-Nord	219	Saint-Brieuc (Côtes-du-Nord).
Chemins de fer Départementaux	1 427	Paris.
Chemins de fer Départementaux de l'Aisne	200	Paris.
Chemins de fer Départementaux des Bouches-du-Rhône.	175	Arles-s/Rhône.
Chemins de fer Départementaux du Tarn	150	Castres-s/Agout. (Tarn).
Société générale des chemins de fer Economiques	2 555	Paris.
Chemins de fer Economiques du Nord	365	Paris.
Chemin de fer de l'Est de Lyon	104	Lyon.
Chemins de fer de Grande Banlieue	240	Paris.
Voies ferrées des Landes	363	Paris.
Compagnie Meusienne de chemins de fer	168	Bar-le-Duc.
Chemins de fer de Saint-Quentin à Guise	65	Paris.
Chemins de fer d'intérêt local de Saône-et-Loire.	192	Mâcon (S.-et-L.).
Chemins de fer de Somain à Anzin et à la frontière belge	34	Anzin.
Chemins de fer du Sud de la France	570	Paris.
Chemins de fer du Sud-Ouest	400	Toulouse (Haute-Garonne).
Chemins de fer d'intérêt local de l'Yonne	142	Joigny (Yonne).
Compagnie générale des chemins de fer vicinaux	390	Paris.
Compagnie générale de voies ferrées d'intérêt local	513	Paris.
Régie départementale des tramways de l'Ain	436	Bourg (Ain).
Tramways départementaux des Deux-Sèvres	198	Paris.
Tramways de l'Indre	198	Paris.

NAMES OF THE ADMINISTRATIONS.	Kilometres.	OFFICES.
b) Algiers and Tunis.		
Chemins de fer algériens de l'Etat	2 532	Alger.
Chemins de fer algériens de la Compagnie Paris-Lyon-Méditerranée	513	Paris.
Chemins de fer de Bône-Guelma et prolongements	1 550	Paris.
Chemin de fer de Gafsa	441	Paris.
c) Colonies and protectorates.		
Isle of Réunion.		
Chemin de fer du Port de la Pointe des Galets	127	Paris.
Senegal.		
Chemin de fer de Dakar à Saint-Louis	264	Paris.
ASIA MINOR.		
Société ottomane du chemin de fer de Damas-Hamah et prolongements	480	Paris.
Chemin de fer Smyrne-Cassaba et prolongement	701	Paris.
THE UNITED KINGDOM, PROTECTORATES, INDIA AND COLONIES.		
a) The United Kingdom.		
I. — *Main Companies.*		
Caledonian Railway	1 793	Glasgow.
Glasgow & South Western Railway	771	Glasgow.
Great Central Railway	1 596	London.
Great Eastern Railway	1 711	London.
Great Northern Railway	1 596	London.
Great Western Railway	4 269	London.
London and North Western Railway	4 958	London.
London, Brighton and South Coast Ry.	784	London.
London and South Western Railway	1 664	London.
Midland Railway	2 224	Derby.
Midland Great Western Ry. of Ireland	866	Dublin.
North British Railway	2 218	Edinburgh.
North Eastern Railway	2 828	York.
South Eastern and Chatham Ry.	1 038	London.

NAMES OF THE ADMINISTRATIONS.	Kilometres.	OFFICES.
II. — *Other Railways.*		
Barry Railway	103	Barry-Docks.
Cambrian Railways	483	Oswestry.
Cheshire Lines Committee	220	Liverpool.
City and South London Railway	11	London.
Cork, Bandon and South Coast Ry.	151	Cork.
Dublin and South Eastern Railway	251	Dublin.
Furness Railway	275	Barrow-in-Furness.
Great Northern Railway (Ireland)	896	Dublin.
Great North of Scotland Railway	538	Aberdeen.
Great Southern and Western Railway	1 820	Dublin.
Highland Railway	792	Inverness.
Hull and Barnsley Railway	128	Hull.
Isle of Man Railway	74	Douglas.
Kent, Somerset and Shropshire Light Railways Group	153	Tonbridge.
Liverpool Overhead Railway	16	Liverpool.
Londonderry and Lough Swilly and Letterkenny Rys.	161	Londonderry.
Metropolitan Railway	127	London.
Neath and Brecon Railway	64	Neath.
North Staffordshire Railway	325	Stoke-upon-Trent.
Rhondda and Swansea Bay Railway	45	Swansea.
Rhymney Railway	127	Cardiff.
Stratford-on-Avon and Midland Junction Ry.	105	Stratford-on-Avon.
Taff Vale Railway	200	Cardiff.
Tralee and Dingle Railway	60	Tralee.
County Donegal Railways Joint Committee	201	Stranorlar.
Great Central and Midland Joint Committee	63	London.
Great Northern and Great Eastern Joint Committee	198	London.
Midland Rys. and Great Northern Joint Committee	295	Derby.
Midland Rys. (Northern Counties Committee)	423	Belfast.
Railway Clearing House		London.
***b*) India, protectorates and Colonies.**		
I. — *India.*		
Bengal Nagpur Railway	4 338	Calcutta.
Bengal and North Western Railway	3 304	London.
Bombay, Baroda and Central India Ry.	6 316	London.

NAMES OF THE ADMINISTRATIONS.	Kilo-metres.	OFFICES.
Eastern Bengal Railway (State Ry. of India)	2 797	Calcutta.
Great Indian Peninsula Railway	5 023	Bombay.
Madras and Southern Mahratta Ry.	4 873	London.
North Western Railway (State Ry. of India)	8 883	Lahore.
Oudh and Rohilkhand Ry. (State Ry. of India)	2 562	Lucknow.
South Indian Railway	2 980	London.
II. — *Africa.*		
Nigerian Railway	1 814	Lagos.
South African Railways and Harbours	15 274	Johannesburg.
Mashonaland Railway	602	London.
III. — *Australia*		
New South Wales Government Rys.	8 071	Sydney.
New Zealand Government Railways	4 838	London.
South Australia Government Railways	3 754	Adelaïde.
IV. — *Canada.*		
Grand Trunk Railway	3 003	Montreal.
Quebec Central Railway	446	Sherbrooke, P. Q.
V. — *Malay Peninsula.*		
Federated Malay States Railways	1 613	Kuala Lumpur.
GREECE.		
Chemins de fer de l'Etat hellénique	1 848	Athènes.
Chemins de fer du Nord-Ouest de Grèce	74	Athènes.
Chemins de fer de Thessalie	233	Athènes.
HAYTI.		
ITALY.		
I. — *Lines of the State.*		
Chemins de fer de l'Etat	16 164	Rome.
II. — *Private lines.*		
Chemins de fer de la Méditerranée	173	Milan.
Chemins de fer du Nord de Milan	238	Milan.

NAMES OF THE ADMINISTRATIONS.	Kilo-metres.	OFFICES.
Société Emilienne de chemins de fer, tramways et automobiles	120	Modène.
Société Vénitienne pour la construction et l'exploitation de chemins de fer secondaires en Italie	558	Padoue.
Chemins de fer de l'Apennin central	135	Milan.
Chemin de fer Central et tramways du Canavèse	59	Turin.
Chemins de fer de Reggio-Emilia	71	Reggio-Emilia.
Chemins de fer complémentaires de la Sardaigne	697	Cagliari.
Chemins de fer de Suzzara-Ferrara	82	Milan.
Société anonyme des tramways de Lombardie et Romagnes, Réseaux de Brescia-Mantoue-Ostiglia-Desenzano et Forli-Meldola-Forli-Ravenne-Classe	175	Liége.
Société nationale de chemins de fer et de tramways	150	Rome.
Tramways à vapeur piémontais	180	Bruxelles.
Tramways à vapeur et chemins de fer économiques de la province de Pise	41	Pise.
Tramways et chemins de fer économiques de Rome-Milan-Bologne	31	Bruxelles.
Chemin de fer du Tessin	242	Bruxelles.
Société anonyme pour les chemins de fer vicinaux	136	Rome.
Société sicilienne de travaux publics (Chemin de fer « Circum etnea »)	114	Paris.
Société turinoise de tramways et de chemins de fer économiques	76	Turin.
Tramways Vercellesi	112	Vercelli.
Fédération des transports	3 020	Milan.
JAPAN.		
LUXEMBURG.		
Chemins de fer Guillaume-Luxembourg	257	Luxembourg.
Chemins de fer et Minières Prince-Henri	250	Luxembourg.
MEXICO.		
NICARAGUA.		
NORWAY.		
I. — *Lines of the State.*		
Chemins de fer de l'Etat	2 820	Christiania.
II. — *Private line* (large gauge track).		
Chemin de fer de Christiania à Eidsvold	68	Christiania.

NAMES OF THE ADMINISTRATIONS.	Kilometres.	OFFICES.
PARAGUAY.		
HOLLAND.		
a) **Continent.**		
I. — *Main lines.*		
Compagnie pour l'exploitation des chemins de fer de l'Etat néerlandais	2 190	Utrecht.
Chemin de fer Hollandais	1 489	Amsterdam.
II. — *Light railways.*		
Tramway à vapeur de Breskens à Maldegem	42	Breskens.
Tramways à vapeur sud-néerlandais	100	Breda.
b) **Colonies.**		
Chemins de fer de l'Etat aux Indes néerlandaises	3 660	Weltevreden.
Société des chemins de fer aux Indes néerlandaises	749	La Haye.
Tramway à vapeur Semarang-Cheribon	390	La Haye.
PERU.		
Lima Railways	32	London.
POLAND.		
PORTUGAL.		
a) **Continent.**		
I. — *Lines of the State.*		
Chemins de fer de l'Etat	1 329	Lisbonne.
II. — *Private lines.*		
Chemins de fer portugais de la Beira-Alta	253	Paris.
Compagnie des chemins de fer portugais	1 073	Lisbonne.
Compagnie nationale des chemins de fer portugais	185	Lisbonne.
b) **Colonies.**		
Chemins de fer de l'Etat	1 049	Lisbonne.

NAMES OF THE ADMINISTRATIONS.	Kilometres.	OFFICES.
RUMANIA.		
Chemins de fer de l'Etat	10 258	Bucarest.
SALVADOR.		
Salvador Railway	161	London.
KINGDOM OF SERVIANS, CROATIANS AND SLOVENIANS.		
Chemins de fer de l'Etat	1 591	Belgrade.
SIAM.		
SWEDEN.		
I. — *Lines of the State.*		
Chemins de fer de l'Etat	5 582	Stockholm.
II. — *Private lines.*		
Chemin de fer Bergslagen	552	Göteborg.
Chemin de fer Blekinge Kustbanor	168	Ronneby.
Chemin de fer de Frövi-Ludvika	98	Kopparberg.
Chemin de fer Gefle-Dala	293	Gefle.
Chemin de fer Halmstad-Nässjö	411	Halmstad.
Chemin de fer Helsingborg-Hessleholms	122	Helsingborg.
Chemin de fer Kalmar-Nya	195	Kalmar.
Chemin de fer Karlstad - Munkfors - Nordmarks - Klarelfvens-Filipstads - Norra - Bergslagen	171	Hagfors.
Chemin de fer Mellersta-Oestergötland	125	Linköping.
Chemin de fer Nässjö-Oskarshamn	148	Eksjö.
Chemin de fer Nora-Bergslagen	173	Nora.
Chemin de fer Nora-Oestergoetland	134	Finspong.
Chemin de fer Norrköping-Söderköping Vikbolandet	102	Norrköping.
Chemin de fer Norsholm-Westervik-Hultsfred	245	Westervik.
Chemin de fer Stockholm-Roslag	200	Stockholm.
Chemin de fer Stockholm-Vesteras-Bergslagen	479	Stockholm.
Chemin de fer Uddevalla-Venersborg-Herrljunga	92	Venersborg.
Chemin de fer Västergotland-Göteborg	365	Göteborg.

NAMES OF THE ADMINISTRATIONS.	Kilometres.	OFFICES.
SWITZERLAND.		
I. — *Standard gauge-track railways.*		
Chemins de fer fédéraux	2 906	Berne.
Chemins de fer des Alpes Bernoises Berne-Loetschberg-Simplon	253	Berne.
II. — *Narrow gauge-track railways.*		
Chemin de fer de la vallée de Birsig	17	Bâle.
Chemin de fer Rhétique	276	Chur.
Chemin de fer de Viège à Zermatt	35	Lausanne.
Chemin de fer d'Yverdon à Sainte-Croix	25	Yverdon.
Chemin de fer de Lausanne à Ouchy	2	Lausanne.
CZECHO-SLOVAKIA.		
Chemins de fer de l'Etat	12 402	Prague.
Aussig-Teplitzer Eisenbahn	346	Teplitz-Schönau.
URUGUAY.		
Central Uruguay Railway of Montevideo	1 577	London.
North Western of Uruguay Railway	182	London.

NEW BOOKS AND PUBLICATIONS

[625 .6 (02 & 385. (04]

CUËNOT (G.), chief engineer of bridges and highways. — **Chemins de fer d'intérêt local et tramways (Light railways and tramways).** — One volume 8vo (10 × 6 1/2 inches) of 295 pages. — 1921. Ch. Béranger, publisher, 15, rue des Saints-Pères, Paris; 210, rue de la Régence, Liége. — Net price : 25 francs, plus 2 francs for postage and packing.

In this treatise, Mr. Cuënot deals with the general situation of the light railways and tramways. This investigation was made during the war, since which time the difficulties encountered in constructing and operating railways have been still further increased. The author draws attention to a number of mistakes in construction, operation, etc., which are commonly found on this class of railway. The light railways and tramways from a constructional point of view have much in common with the ordinary railways, but as the author shows, the conditions under which they operate are totally different to those of the latter. Moreover, the majority of these lines are worked at a loss. They are badly managed, and no serious and systematic attempt is made to work them on approved methods. What is the reason for all this? It is because of insufficient legislative control. This is the conclusion arrived at by the author after investigation of the construction and operation of the light railways. In the last chapter, the author concludes by asking how these defects are to be overcome, and he summarises his conclusions as follows :

« In place of the present very imperfect system, there should be substituted a system of government control, but not of state ownership, which would lead to still greater abuses and which would cause them to suffer from the bad effects of political influence. » It is also necessary « to suspend temporarily the working of unprofitable lines in cases where the receipts are insufficient to meet the working expenses ».

The book is divided into seven chapters. We give below a summary of the contents :

CHAPTER I. — *Construction.*

I. General remarks.
II. Construction of the line.
III. Rolling stock.

CHAPTER II. — *Motive power.*

I. Railways worked by autocars or locomotives.
II. Tramways worked from a central power station.
III. Cases where power is produced by a central power station but stored in accumulators on the vehicles.

CHAPTER III. — *The operation of light railways from a technical point of view.*

CHAPTER IV. — *The operation of light railways from a commercial point of view.*

A. General remarks.
B. Passenger fares.
C. Parcels traffic.
D. Fast goods traffic.
E. Slow goods traffic.

CHAPTER V. — *Historical.*

CHAPTER VI. — *Legislation.*

CHAPTER VII. — *The financial situation.*

CHAPTER VIII. — *Résumé and conclusions.*

J. V.